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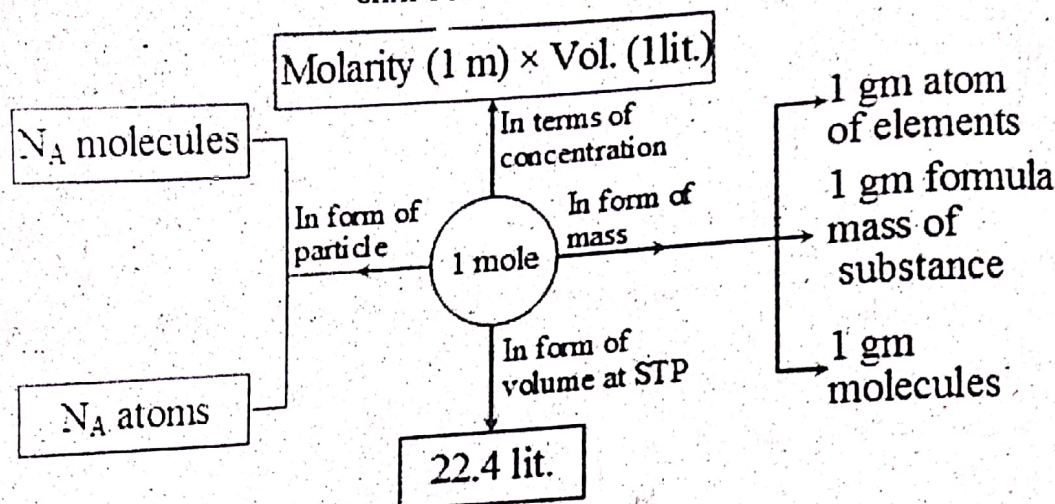
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CHAPT NO.1 STOICHIOMETRY



- Chemistry is a **physical science** which deals with the materials universe.
- Stoichiometry is a quantitative chemistry which deals with the calculations based on balanced chemical equation.
- Avogadro's number is a constant number equal to 6.023×10^{23} . One mole of any pure substance contains Avogadro's number of particles.
- The idea of mole can be applied to chemical equations to calculate the amount of reactants consumed or that of the product formed.
- Stoichiometry problems can be solved, using mol, mol mass and mass mass conversions.
- In cases, where gases are involved, the concept of molar volume of the gas at STP (22.4 dm^3) is helpful to calculate the number of mole and volumes.
- Theoretical yield of reaction is the yield calculated from balanced chemical equation.
- Actual yield is the yield obtained during experimental work.
- Chemists use percentage yield to express the efficiency of a chemical reaction.

Atomicity

- This term is not in the book but important for ETEA, atomicity is the number of atoms in a compound like
- Atomicity of water is three because it has two hydrogen and one oxygen atom.

Quantitative analysis

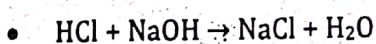
- Glucose $\rightarrow$ diabetes
- Steroids + stimulants $\rightarrow$ athletes
- Cholesterol $\rightarrow$ blood of diabetes
- Dozen 12
- Gross 144

Mole N_A **Mole**

- Atomic mass $\rightarrow$ element
 - 1 mol Na = 23 g of Na
 - 1 mol O = 16 g Oxygen
- Molecular mass $\rightarrow$ compound
 - 1 mol water = 18 g water
- Formula mass $\rightarrow$ ionic compound
 - 1 mol NaCl = 58.5 g NaCl

No of moles

- Mass/molar mass
- No of particles/ N_A
- No of formula units/ N_A
- Volume/molar volume (22.4 dm^3)

Neutralization reaction**STP**

- 0°C or 273 K
- 1 atm
- $\text{dm}^3 = 1 \text{ litre} = 1000 \text{ cm}^3$
- % of an element = $(\text{total mass of an element} / \text{total mass of compound}) \times 100$
- Sum of all percentages must equal to 100

PERCENTAGE COMPOSITION

- Percentage composition of a compound is number of grams of each element per 100g of the compound,
- Sum of all percentages = 100
- %age of an element = $[\text{mass of the element} / \text{total mass}] \times 100$

Excess and limiting reagent

- Limiting reagent in a chemical reaction is the one consumed earlier or which gives least AMOUNT OF PRODUCT FROM BALANCE CHEMICAL EQUATION.
- Excess reagent is the one, which is left behind calculated from the balanced chemical equation.

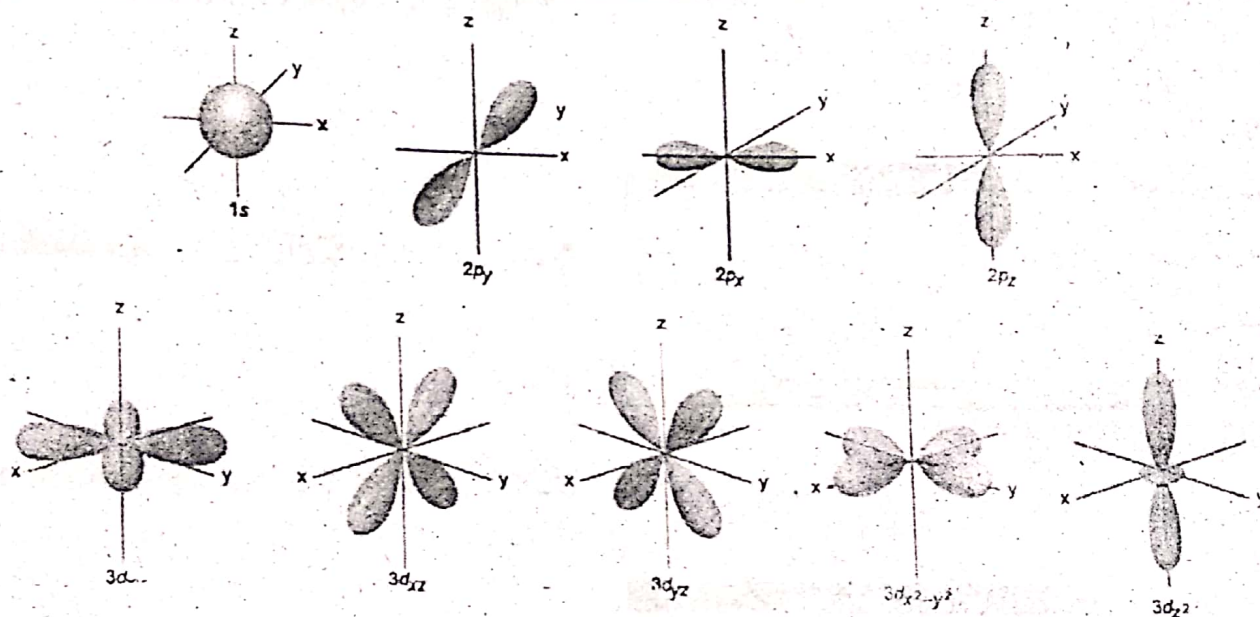
How to find limiting reagent;

- Convert all given masses into mmoles.
- Using balanced chemical equation.
- Find p[roduct according to all products.

- The reactant which gives less product is limiting reagent.

Actual yield is less than theoretical because of

- Reversibility
- Side reaction
- Mechanical loss
- Human error
- Reaction condition (conc, T and P)

CHAP NO.2 ATOMIC STRUCTURE

- The current day knowledge about the structure of atom is the result mainly three types of experiments. The discharge tube experiments, radio activity and spectroscopy.
- Electron, proton neutron are the fundamental particles of all kinds of matter.
- Cathode rays in the discharge tube experiment are impact electrons and the canal rays (When hydrogen gas is in the discharge tube) are protons.
- e/m ratio of electron was determined by J.J. Thomson while charge on the electron, by Millikan.
- Electron is 1836 times lighter than proton.
- Rutherford (1911) discovered nucleus of atoms.
- Max Planck developed quantum theory of radiation and said that radiation emitted and absorbed by a body does not propagate in a continuous form.
- They, rather, propagate in the form of small packets called quanta. He proposed the equation $E = h\nu$ for the energy of quantum.
- Bohr (1913) gave atomic model for hydrogen on the basis of quantum theory and was successful to give equations for the calculations of the radius, energy, frequency, wave length and wave number of the electron, revolving on fixed circular path.
- Hydrogen spectrum can be best explained by Bohr's atomic model.
- X-rays are high frequency radiation, discovered by Rontgen in 1895. They can be produced by hitting the metal surface by high energy electron beam.
- Quantum numbers are a set of numbers which designate an electron in an atom. These are four in number.
- de Broglie, Davisson Germer, Heisenberg and Schrodinger etc. are the main scientists who

contributed their efforts towards the present day.
Knowledge, concerning structure of an atom.

- The name "electron" was given to cathode rays by G.J. Stoney (1874)
- The charge to mass ratio of an electron was determined by J.J. Thomson (1897)
- e/m ratio of electron $1.7588 \times 10^{11} \text{ C/Kg}$
- Charge of electron $-1.6022 \times 10^{-19} \text{ C}$
- Charge of proton $+1.6022 \times 10^{-19} \text{ C}$
- Proton was discovered by E. Goldstein (1886)
- To Bunsen flame Ba (barium) imparts Green colour
- To Bunsen flame Na (sodium) imparts Yellow colour
- To Bunsen flame Sr (strontium) imparts Red colour
- To Bunsen flame K (potassium) imparts Violet colour
- Candescent $\rightarrow$ light by heat
- Charcoal $\rightarrow$ desired colour $\rightarrow$ proper time
- Sodium $\rightarrow$ gold or yellow colour
- Zinc $\rightarrow$ smoke effect

constants

- $h = 6.6262 \times 10^{-34} \text{ Js}$
- $k = 9 \times 10^9$
- $c = 2.99 \times 10^8 \text{ m/s}$
- $R = 1.097 \times 10^7$

masses

- Electron $\rightarrow 9.11 \times 10^{-31}$
- proton $\rightarrow 1.6726 \times 10^{-27}$
- neutron $\rightarrow 1.6749 \times 10^{-27}$

Law of Dalton's laws of chemical combination

- Law of conservation of matter
- Law of definite proportion
- Law of multiple proportion
- Goldstein $\rightarrow$ cathode rays
- G.J. Stoney $\rightarrow$ electrons

Cathode rays properties

- Hittorf $\rightarrow 1869 \rightarrow$ straight
- Crooke $\rightarrow 1870 \rightarrow$ mv
- Pierre + Thomson $\rightarrow 1895-97 \rightarrow$ negative
- Thomson $\rightarrow 1897 \rightarrow$ electric field deflection
- Cathode rays $\rightarrow$ high reducing effect
- Heat up foil when hit it
- Produce x-rays by hitting metal
- Ionize the gas
- They have reducing effect.

Charge on electron:

- $4.8 \times 10^{-10} \text{ e.s.u}$ or $1.602 \times 10^{-19} \text{ C}$

For electron

- $e/m = 1.602 \times 10^{-19} / 9.11 \times 10^{-31} = 1.7588 \times 10^{11}$

for proton

- $e/m = 1.602 \times 10^{-19} / 1.6726 \times 10^{-27} = 9.54 \times 10^7$

Plank's quantum theory

- Energy are radiated and absorb in form of quana.
- In case of light energy, quana are called photons.
- Each wave packet energy is related to frequency by $E=hf$
- Energy emitted or absorb are multiple of $hf \rightarrow E=nhf$

$E=hu$

- Wavelength (λ) is the distance between crest and trough.
- Frequency (ν) is the number of waves in one second.
- Wave number ($\bar{\nu}$) is the number of waves per unit length. It is reciprocal of wavelength.

Derivation

$$E=hu$$

$$\text{By putting } c=f\lambda$$

$$E=hc/\lambda$$

$$E=hc\bar{\nu}$$

Bohr model

- Angular momentum is integral multiple of $nh/2\pi$

$$r_n = \frac{Ze^2}{4\pi\epsilon_0 m v^2}$$

$$r_n = \frac{n^2 h^2 \epsilon_0}{\pi Z m e^2} = n^2 0.529 \text{ \AA} = 0.529 \times 10^{-8} \text{ cm}$$

first five Bohr's Radii

$$r = n^2 \times 0.529 \times 10^{-8} \text{ cm}$$

$$n = 1; r = 1^2 \times 0.529 \times 10^{-8} = 0.529 \times 10^{-8} \text{ cm}$$

$$n = 2; r = 2^2 \times 0.529 \times 10^{-8} = 2.12 \times 10^{-8} \text{ cm}$$

$$n = 3; r = 3^2 \times 0.529 \times 10^{-8} = 4.76 \times 10^{-8} \text{ cm}$$

$$n = 4; r = 4^2 \times 0.529 \times 10^{-8} = 8.46 \times 10^{-8} \text{ cm}$$

$$n = 5; r = 5^2 \times 0.529 \times 10^{-8} = 13.2 \times 10^{-8} \text{ cm}$$

$$r_2 - r_1 < r_3 - r_2 < r_4 - r_3 < r_5 - r_4 < \dots$$

$$E_n = -\frac{Z^2 m e^4}{8 n^2 h^2 \epsilon_0^2}$$

$$\text{Energy for Hydrogen} \rightarrow E_n = -\frac{m e^4}{8 n^2 h^2 \epsilon_0^2} = [-2.18 \times 10^{-18}] / n^2 \text{ J/atom} = -1312 / n^2 \text{ kJ/mol}$$

$$E_n = -1312 / n^2 \text{ kJ/mol}$$

$$E_1 = -1312 \text{ kJ/mol}$$

$$E_2 = -328 \text{ kJ/mol}$$

BOM SERIES

- $E_3 = -145 \text{ kJ/mol}$
- $E_4 = -82 \text{ kJ/mol}$
- $E_5 = -52 \text{ kJ/mol}$
- $E_2 - E_1 > E_3 - E_2 > E_4 - E_3 > E_5 - E_4 \dots\dots$
- $f = \frac{Z^2 m e^4}{8 h^3 \epsilon_0^2} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$
- wave number $= f/c = \frac{Z^2 m e^4}{8 h^3 c \epsilon_0^2} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$ for $Z=1$
- $\frac{m e^4}{8 h^3 c \epsilon_0^2} = R$
- $R = \frac{m e^4}{8 h^3 c \epsilon_0^2}$

FROM THE EQUATION

- $R \propto m$
- $R \propto e^4$
- $R \propto 1/hc$
- $\Delta E = 1312 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \text{ kJ/mol}$

Spectrum

rays $\rightarrow$ wavelength (nm)

- gamma $\rightarrow > 0.006$
- x-rays $\rightarrow 0.006 - 8$
- ultra violet $\rightarrow 8 - 380$
- visible $\rightarrow 380 - 760$
- infrared $\rightarrow 760 - 10 \text{ lac}$
- microwaves $\rightarrow 10 \text{ lac} - 30 \text{ crore}$
- radio waves $\rightarrow > 30 \text{ crore}$

Spectral lines

- Transition from $n_2 = 2, 3, 4, 5$ etc to $n_1 = 1$ in hydrogen spectrum gives Lyman series
- Transition from $n_2 = 3, 4, 5, 6$ etc to $n_1 = 2$ in hydrogen spectrum gives Balmer series
- Transition from $n_2 = 4, 5, 6, 7$ etc to $n_1 = 3$ in hydrogen spectrum gives Paschen series
- Transition from $n_2 = 5, 6, 7, 8$ etc to $n_1 = 4$ in hydrogen spectrum gives Brackett series
- Transition from $n_2 = 6, 7, 8, 9$ etc to $n_1 = 5$ in hydrogen spectrum gives Pfund series
- The reverse process of photoelectric effect is X-rays
- The part of electromagnetic spectrum in which Lyman series lie is Ultra violet region
- Lyman series lies in Ultra violet region
- Balmer series lies in Visible region
- Paschen series lies in Near IR region
- Brackett series lies in Mid IR region
- Pfund series lies in region Far IR

Bohr's theory defect

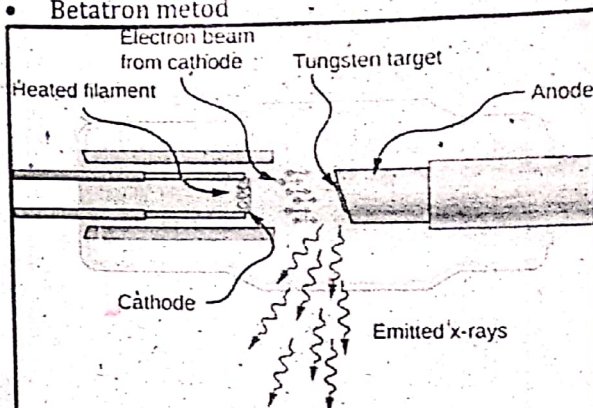
- Can't explain multiplicity of spectral lines
- Can't explain magnetic field effect (Zeeman effect)
- Can't explain electric field effect (Stark effect)

Facebook/Instagram/PlayStore/YouTube: Bank of Moons

- Against Heisenberg's principle

X rays production method

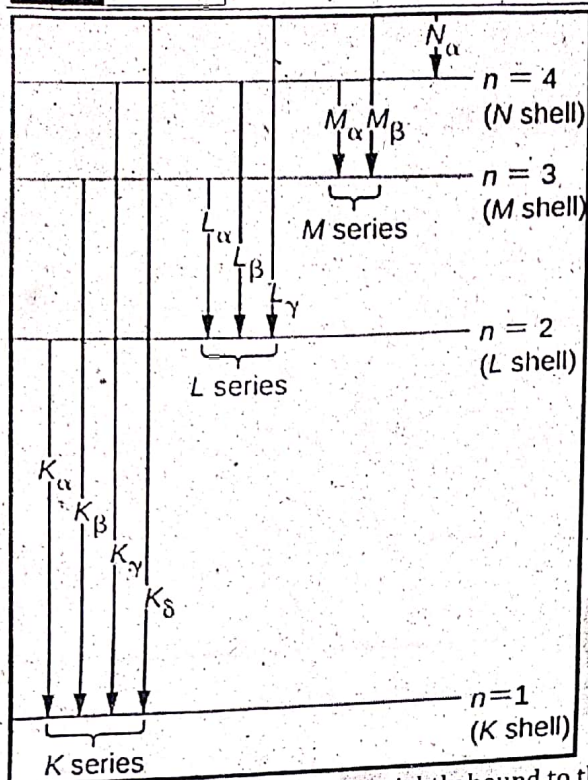
- Roentgen method
- Coolidge method
- Betatron method

**X rays properties**

- Neutral
- Reflected + refracted + diffracted
- Penetrate
- Blacken the photographic plate
- Produce the fluorescence in many substance like rock salt, uranium and glass.

Types of X-rays

- X-ray has three types.
- The energy level of hydrogen are in order of $-13.6 \text{ eV}/n^2$
- The spectrum of hydrogen atom consists of:
 - Ultraviolet region
 - Visible region
 - Infrared region



- The outer shell electrons are tightly bound to the nucleus. Inner shell transitions emit photons of frequency beyond the ultraviolet region and are known as X-rays.
- An X-ray photon due to transmission from L to K shell is called K_α .
- An X-ray photon due to transmission from M to K shell is called K_β .
- An X-ray photon due to transmission from N to K shell is called K_γ .
- An X-ray photon due to transmission from M to L shell is called L_α .
- An X-ray photon due to transmission from N to L shell is called L_β .
- An X-ray photon due to transmission from O to L shell is called L_γ .
- An X-ray photon due to transmission from N to M shell is called M_α .
- An X-ray photon due to transmission from O to M shell is called M_β .
- An X-ray photon due to transmission from P to M shell is called M_γ .

Uses of X-rays

- Medicines
- Diffraction for structure finding.
- Spacing in lattice.
- Ionize the gas.
- To find the Pattern

Moseley's Law

- Moseley (1913) found that the number of positive charges in the nucleus is the fundamental

property of an element. He developed a relationship between frequency of the emitted X-rays radiation, and the number of positive charges (the atomic number) present in the nucleus of an element.

- $\sqrt{\nu} = a(Z-b)$
- $a \rightarrow$ proportionality constant
- $b \rightarrow$ screening constant and its value for K series is 1.
- For K series, Moseley equation is $\sqrt{\nu} = a(Z)$

Quantum numbers

- Bohr's electronic energy shells or levels, designated as Principal Quantum Numbers ' n '.
- Thus there are in all four such identification numbers called **quantum numbers** which fully describe an electron in an atom. Each one of these refers to a particular character.

Principal Quantum Number ' n '

- This quantum number denotes the principal shell to which the electron belongs. This is also referred to as major energy level.
- $r_n = 0.529 n^2 \text{ \AA}$, where n is the principal quantum number of the shell.
- The principal quantum number ' n ' can have non-zero, positive, integral values $n = 1, 2, 3, \dots$ increasing by integral numbers to infinity.
- In a polyelectron atom or ion, the electron that has a higher principal quantum number is at a higher energy level. An electron with $n = 1$ has the lowest energy and is bound most firmly to the nucleus.
- The letters K, L, M, N, O, P and Q are also used to designate the energy levels or shells of electrons with a n value of 1, 2, 3, 4, 5, 6, 7 respectively.
- There is a limited number of electrons in an atom which can have the same principal quantum number and is given by $2n^2$, where n is the principal quantum number concerned.

Principal quantum number (n)	1	2	3	4
Letter designation	K	L	M	N
Maximum number of electrons ($2n^2$)	2	8	18	32

Since Azimuthal Quantum number ' l '

- This is also called secondary or subsidiary quantum number. It defines the spatial distribution of the electron cloud about the nucleus and describes the angular momentum of the electron.
- the quantum number l defines the shape of the orbital occupied by the electron and the angular momentum of the electron.

- sometimes referred to as orbital or angular quantum number. It is for this reason that 'l' is sometimes referred to as orbital or angular quantum number.
- For any given value of the principal quantum number n , the azimuthal quantum number l may have all integral values from 0 to $n - 1$, each of which refers to an Energy sublevel or Sub-shell.
- The total number of such possible sublevels in each principal level is numerically equal to the principal quantum number of the level under consideration. These sublevels are also symbolised by letters s, p, d, f etc.
- for principal quantum number $n = 1$, the only possible value for l is 0 i.e., there is only one possible subshell i.e. s-subshell ($n = 1, l = 0$).
- For $n = 2$, there are two possible values of l , $l = 0$ and $l = 2 - 1 = 1$. This means that there are two subshells in the second energy shell with $n = 2$. These subshells are designated as 2s and 2p.
- Similarly, when $n = 3$, l can have three values i.e. 0, 1 and 2. Thus there are three subshells in third energy shell with designations 3s, 3p and 3d respectively.
- For $n = 4$, there are four possible values of azimuthal quantum number l ($= 0, 1, 2$, and 3) each representing a different sublevel. In other words, the fourth energy level consists of four subshells which are designated as 4s, 4p, 4d and 4f.

$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$
$l = 0$ (1s)	$l = 0$ (2s)	$l = 0$ (3s)	$l = 0$ (4s)	$l = 0$ (5s)
	$l = 1$ (2p)	$l = 1$ (3p)	$l = 1$ (4p)	$l = 1$ (5p)
		$l = 2$ (3d)	$l = 2$ (4d)	$l = 2$ (5d)
			$l = 3$ (4f)	$l = 3$ (5f)
				$l = 4$ (5g)

- For a given value of principal quantum number the order of increasing energy for different subshells is $s < p < d < f$ (except for H atom)

Magnetic Quantum Number 'm'

- This quantum number has been proposed to account for the splitting up of spectral lines (Zeeman Effect)
- An application of a strong magnetic field to an atom reveals that electrons with the same values of principal quantum number ' n ' and of azimuthal quantum number ' l ', may still differ in their behaviour. They must, therefore, be differentiated by introducing a new quantum number, the magnetic quantum number m .

- This is also called Orientation Quantum Number because it gives the orientation or distribution of the electron cloud.
- For each value of the azimuthal quantum number ' l ', the magnetic quantum number m , may assume all the integral values between $+l$ to $-l$ through zero i.e., $+l, \dots, 0, \dots, -l$. Therefore for each value of l there will be $(2l + 1)$ values of m .
- when $l = 0, m = 0$ and no other value. This means that for each value of principal quantum number ' n ', there is only one orientation for $l = 0$ (s orbital) or there is only one s orbital.
- For s orbital, there being only one orientation, it must be spherically symmetrical about the nucleus. There is only one spherically symmetrical orbital for each value of n whose radius depends upon the value of n .
- For $l = 1$ (p orbital), the magnetic quantum number m will have three values: $+1, 0$ and -1 ; so there are three orientations for p orbitals. These three types of p orbitals differ only in the value of magnetic quantum number and are designated as p_x, p_y, p_z depending upon the axis of orientation. The subscripts x, y and z refer to the coordinate axes. In the absence of a magnetic field, three p orbitals are equivalent in energy and are said to be three-fold degenerate or triply degenerate.
- Different orbitals of equivalent energy are called degenerate orbitals and are grouped together.
- In presence of an external magnetic field the relative energies of the three p orbitals vary depending upon their orientation or magnetic quantum number. This probably accounts for the existence of more spectral lines under the influence of an external magnetic field.
- The p orbital are of dumb-bell shape consisting of two lobes. The two lobes of a p orbital extend outwards and away from the nucleus along the axial line. Thus the two lobes of a p orbital may be separated by a plane that contains the nucleus and is perpendicular to the corresponding axis. Such plane is called a nodal plane. There is no likelihood of finding the electron on this plane.
- For a p_x orbital, the yz plane is the nodal plane.
- For $l = 2$ (d orbital), the magnetic quantum number are five ($2 \times 2 + 1$): $+2, +1, 0, -1, -2$. Thus there are five possible orientations for d orbitals which are equivalent in energy so long as the atom is not under the influence of a magnetic field and are said to be five-fold degenerate (Different orbitals of equivalent energy are called degenerate orbitals and are grouped together). The five d orbitals are designated as $d_{xy}, d_{yz}, d_{zx}, x^2 - y^2, dz^2$.
- When $l = 3$ (f orbital) the magnetic quantum number m can have seven ($2 \times 3 + 1$) values as $+3, +2, +1, 0, -1, -2$ and -3 . These seven orientations give rise to a set of seven-fold

degenerate orbitals. These seven orbitals possess very complicated shapes.

Spin Quantum Number 's'

- This quantum number has been introduced to account for the spin of electrons about their own axis. Since an electron can spin clockwise or anticlockwise (in two opposite directions), there are two possible values of s that are equal and opposite.

- As quantum numbers can differ only by unity from each other, there are two values given to $+2/3$ and $-1/2$ depending upon whether the electron spins in one direction or the other.
- These spins are also designated by arrows pointing upwards and downward as $\uparrow\downarrow$.
- Two electrons with the same sign of the spin quantum numbers are said to have parallel spins while those having opposite signs of the spin quantum numbers are said to have opposite spin or antiparallel spin or paired-up spin.

n	Possible values of l	Subshell designation	Possible values m values	Number of orbitals in subshell	Total number of orbitals in shell
1	0	1s	0	1	1
2	0	2s	0	1	4
	1	2p	-1, 0, 1	3	
3	0	3s	0	1	9
	1	3p	-1, 0, 1	3	
	2	3d	-2, -1, 0, 1, 2	5	
4	0	4s	0	1	16
	1	4p	-1, 0, 1	3	
	2	4d	-2, -1, 0, 1, 2	5	
	3	4f	-3, -2, -1, 0, 1, 2, 3	7	

QUANTUM NUMBER	LETTER	VALUES	MAXIMUM ES
Principle quantum number	n	K $\rightarrow$ 1, L $\rightarrow$ 2	$2n^2$
Azimuthal quantum number	l	0 to n-1	$2(2l+1)$
Magnetic quantum number	m	-l to 0 to +l	$2l+1$
Spin quantum number	s		

- S $\rightarrow$ spherical
- P $\rightarrow$ dumbbell
- D $\rightarrow$ sausage
- F $\rightarrow$ complicated
- Parallel spin $\uparrow\uparrow$
- Antiparallel or pair up spins $\uparrow\downarrow$

NODES

- Total nodes = angular + radial nodes = n-1
- Angular nodes = l
- Radial nodes = (n-1) - l

CONFIGURATION

Electronic configuration:

- An orbital is a region of space around the nucleus where the probability of finding electron is maximum.
- Aufbau principle, Pauli's exclusion principle and Hund's rule are followed for the distribution of electrons in various orbitals of a poly electron (multi electron) atom.

Aufbau principle

- building up principle.
- This rule is based on n+l rule.
- Electrons are first filled in orbitals with lower n+l rule.
- If two have same n+l rule, the one having lower n will be of lower energy.

Sub orbital	N+l rule
3s	$3+0=3$
3p	$3+1=4$
3d	$3+2=5$
4d	$4+0=4$

- $3p < 4d < 3d$ w.r.t energy

1s					
2s	2p				
3s	3p	3d			
4s	4p	4d	4f		
5s	5p	5d	5f	5g	
6s	6p	6d	6f	6g	
7s	7p	7d	7f	7g	
8s	8p	8d	8f	8g	
9s	9p	9d	9f	9g	

(e) angular nodes in sub shell = $l(2l+1)$ (f) total number of radial nodes in orbital = $n-l-1$, like

- $1s = 1 - 0 - 1 = 0$
- $2s = 2 - 0 - 1 = 1$
- $2p = 2 - 1 - 1 = 0$
- $3s = 3 - 0 - 1 = 2$
- $3p = 3 - 1 - 1 = 1$
- $3d = 3 - 2 - 1 = 0$

Number of orbitals(a) number of orbitals in shells = n^2 , like

- $K = (1)^2 = 1$ orbital
- $L = 2^2 = 4$ orbitals
- $M = 3^2 = 9$ orbitals
- $N = 4^2 = 16$ orbitals
- $N = 5^2 = 25$ orbitals and so on

(b) number of orbitals in sub shell = $2l+1$

- $S = 2 \times 0 + 1 = 1$ orbital
- $P = 2 \times 1 + 1 = 3$ orbitals
- $D = 2 \times 2 + 1 = 5$ orbitals
- $F = 2 \times 3 + 1 = 7$ orbitals

Number of electrons:(a) Number of electrons in shell/orbit = $2(n)^2$

- $K = 2(1)^2 = 2$ electrons
- $L = 2(2)^2 = 8$ electrons
- $M = 2(3)^2 = 18$ electrons
- $N = 2(4)^2 = 32$ electrons
- $O = 2(5)^2 = 50$ electrons
- $P = 2(6)^2 = 72$ electrons and so on

(B) Number Of Electrons in sub shell = $2(2l+1)$

- $S = 2(2 \times 0 + 1) = 2$ electrons
- $P = 2(2 \times 1 + 1) = 6$ electrons
- $D = 2(2 \times 2 + 1) = 10$ electrons
- $F = 2(2 \times 3 + 1) = 14$ electrons
- In any orbitals there are only 2 electrons

Pauli's principle

- No 2 electrons have same quantum numbers set.
- Electrons in same orbit must have opposite spin.

Hund's rule

- degenerate orbitals have same energy.
- If 2 electrons have to fill more than one orbitals, they will move separately to orbitals instead of leaving in one orbit.

Number of Nodes,(a) Total nodes = $n-1$ like

- $1s = 1 - 1 = 0$
- $2s = 2 - 1 = 1$
- $2p = 2 - 1 = 1$
- $3s = 3 - 1 = 2$
- $3p = 3 - 1 = 2$

(b) total nodes in sub shell = $(2l+1)(n-1)$ (c) Total nodes in orbit = $n^2(n-1)$ or n^2l (d) angular nodes in orbital = l like

- $S = 0 =$ zero angular orbitals
- $P = 1 =$ one angular orbital
- $D = 2 =$ 2 angular orbitals
- $F = 3 =$ three angular orbitals

Since 2016

CHAP NO.3 THEORIES OF COVALENT BOND AND SHAPES OF MOLECULES

Formula	BeCl ₂	BCl ₃	CH ₄	NH ₃	H ₂ O
	Beryllium chloride	Boron trichloride	Methane	Ammonia	Water
Bonding Pairs	2	3	4	3	2
Valence Electrons	2	3	4	5	6
Lone Pairs	0	0	0	1	2
Angles between bonding pairs		120°	109.5°	107°	105°
Name of shape	Linear	Trigonal Planar	Tetrahedral	Trigonal Pyramid	Bent
					

VSEPR THEORY

- Electrons arrange in such way to minimize repulsion.
- Space occupation; Lone pair - lone pair > lone pair - bond pair > bond pair - bond pair
- Multiple bonds behave like single bond
- Overall geometry depends upon the number of electron pairs in the valence shell of the central atom.

Shapes Of Molecules (Application Of VSEPR)

Compound	Structure	Angle
BeCl ₂	Linear	180°C
BF ₃	triangular planar	120°C
SnCl ₂	Angular structure	Less than 120°C
CH ₄	Tetrahedral structure	109.5°C
NH ₃	Triangular structure	107.5°C
H ₂ O	Angular structure	104.5°C

A phenomenon in which two or more structures can be written for single compound is called resonance.

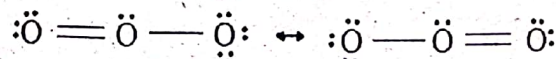
- Ingold called this phenomenon, mesomerism (an intermediate structure)
- Heisenberg called this phenomenon resonance and provide a theoretical background for this.

Conditions for resonance.

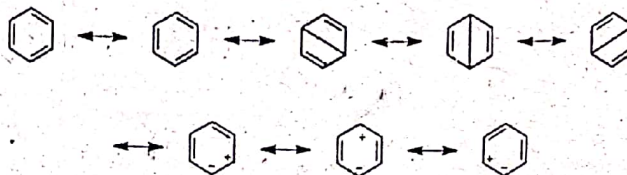
- Nuclei in each structure must same
- Structure is different by electrons position
- Number of unpaired electrons in each structure is same.
- The bond energy of resonance hybrid is lower than calculated value

Examples:

- Ozone



- Benzene



Resonance

Valence Bond Theory

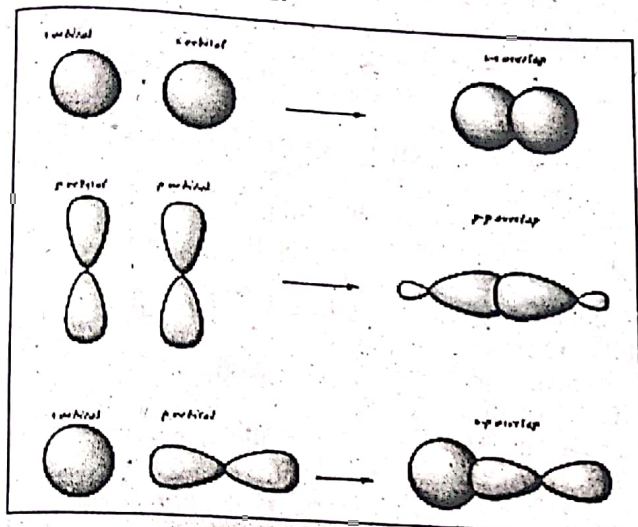
Assumptopns

- Covalent bond is formed by overlapping of orbital.
- Only half filled orbitals make bond.
- Spin of electrons in bond are opposite.
- No of covalent = no of unpaired electrons

Types of Bonds:

a. sigma bond

- s-s overlap $\rightarrow$ H-H
- s-p overlap $\rightarrow$ H-Cl
- p-p overlap $\rightarrow$ Cl-Cl



b. pi bond

- This type of covalent bond is formed by the sidewise overlap of the half filled atomic orbitals.
- It is also called **lateral** or **sidewise** overlap. This type of overlapping takes place perpendicular to the internuclear axis as shown below.

Hybridization

Hybridization	e.g.	Angle
sp^3	Methane	109.5°
sp^2	Ethane	120°
sp	Acetylene	180°
dsp^2	$[PtCl_4]^{2-}$	90°
dsp^3	PCl_5	$90^\circ, 120^\circ$
$d^2 sp^3$	$K_4[Fe(CN)_6]$	90°

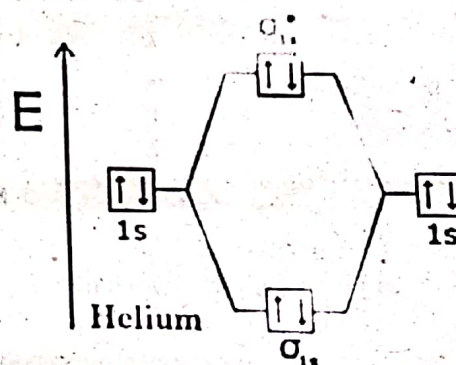
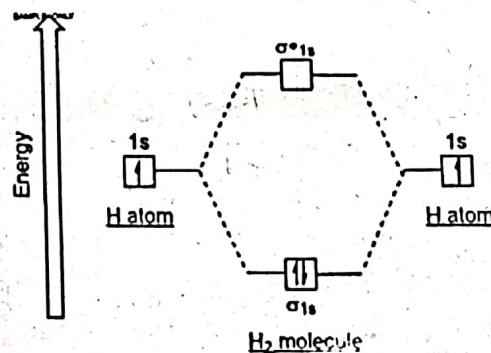
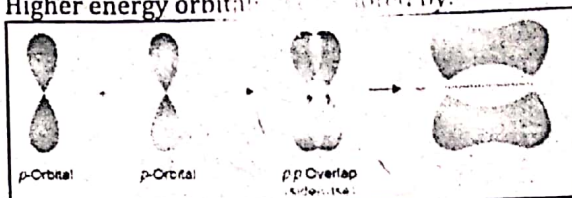
Lower energy $\rightarrow$ bonding molecular orbital $\rightarrow$ sigma and pi

Higher energy $\rightarrow$ anti bonding $\rightarrow$ sigma star and pi star

Bond order = (pair of bonding molecular orbital - pair of anti-bonding molecular orbital) / 2

Molecular Orbital Theory

- All atomic orbitals of the atoms participating in bonding get disturbed when the concerned nuclei approach each other. They all get mixed up to give rise to an equal number of new orbitals called molecular orbitals.
- The molecular orbitals possess different energies, one of lower energy and other of high energy.
- Lower energy orbitals are denoted by σ and π .
- Higher energy orbitals are denoted by σ^* and π^* .



Bond order

- Bond order = [electron pair in bonding molecular orbital - electron pair in antibonding molecular orbital] / 2
- $H_2 \rightarrow 1$
- $He_2 \rightarrow 0$
- $O_2 \rightarrow 2$
- $N_2 \rightarrow 3$

Significance of MOT:

- It shows bond is feasible or not.
- Molecule is Stable $\rightarrow n_b > n_a$
- Molecule is Unstable $\rightarrow n_b < n_a$
- greater the bond order, greater the bond dissociation energy, smaller the bond length.

- Mit explained presence of unpaired electrons in oxygens which makes it paramagnetic in nature.

Bond energies

- Energy need to break one mole $H_2 \rightarrow 436 \text{ KJ/mol}$
- Energy contributed by $H \rightarrow 36.21 \times 10^{-23} \text{ KJ/mol}$
- Energy contributed by $Cl \rightarrow 19.73 \times 10^{-23} \text{ KJ/mol}$
- Expected energy for $HCl \rightarrow 55.94 \times 10^{-23} \text{ KJ/mol}$
- Experimentally energy for $HCl \rightarrow 72.39 \times 10^{-23} \text{ KJ/mol}$
- The higher than calculated value shows that bond in HCl is polar and is stronger than non polar bond
- Bond length is inversely proportional to bond order.
- $\rightarrow$ greater the charge difference, greater is the bond dissociation energy

Bond Length

- $C \rightarrow 77 \text{ pm}$ ($C-C \rightarrow 154 \text{ pm}$)
- $Cl \rightarrow 99 \text{ pm}$ ($Cl-Cl \rightarrow 198 \text{ pm}$)
- $H \rightarrow 37 \text{ pm}$
- $H-Cl \rightarrow 136$ (expected)
- $H-Cl \rightarrow 127 \text{ pm}$ (experimentally)
- The calculated values are always higher than experimental values for heteronuclear molecules.

Energy difference trend

- $HF > HCl = HBr > HI$

Ionic character, if E.N difference is

- Less than 0.9 $\rightarrow$ non polar
- Between 0.9-1.7 $\rightarrow$ polar to some ionic character
- Greater than 1.7 $\rightarrow$ ionic

Dipole moment (vector)

- SI unit Cm other unit is debye
- $1D = 3.34 \times 10^{-30} \text{ Cm}$
- Measure by electric condenser
- % of ionic character = $(\mu_{\text{observed}} / \mu_{\text{ionic}}) \times 100$

Dipole moment for

- Water $\rightarrow 1.84 D$
- $CO_2 \rightarrow$ zero
- $CO \rightarrow$ has dipole

dependence

- Physical properties $\rightarrow$ intermolecular forces (Vander waal)

- Chemical properties $\rightarrow$ intramolecular forces

Reaction between

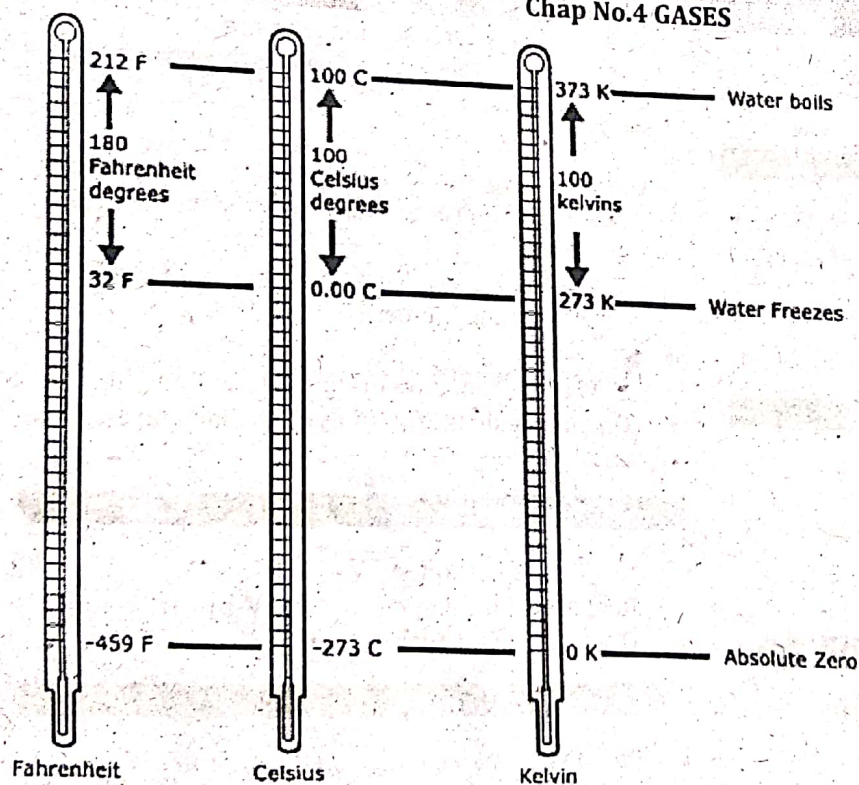
- Covalent $\rightarrow$ slow
- Ionic $\rightarrow$ fast
- Mixing of silver nitrate and sodium chloride solutions produces a white ppt of silver chloride
- Ionic $\rightarrow$ non-directional
- Covalent $\rightarrow$ direction
- All single covalent bonds are Sigma bonds
- $Pi(\pi)$ bond is weaker than Sigma bond (σ)
- Bond order of N_2 is 3σ
- Molecule is stable if $n_b > n_a$
- Greater the bond order, greater the Bond dissociation energy
- The energy required to break a bond and form neutral atoms Bond energy
- Bond energy is measure of strength of a bond which depends upon Electronegativity, size of atom and bond length
- The bond energy for H (Hydrogen) atom is $36.21 \times 10^{-23} \text{ KJ per mole}$
- The bond energy for Cl (Chlorine) atom is $19.73 \times 10^{-23} \text{ KJ per mole}$
- The bond energy for HCl (Hydrochloric Acid) is $72.39 \times 10^{-23} \text{ KJ per mole}$
- Bond energy for HCl is more than calculated value it shows that HCl is Polar
- Greater the charge difference between bonded atoms, Greater will be the Additional bond energy
- Bond length are measured in $\text{\AA}$, nm and Pm
- $C-C$ length is 154 Pm
- $Cl-Cl$ bond length is 198 Pm
- The calculated value of bond length is higher than experimental for Heteronuclear molecule
- A molecule composed of two identical atoms, is always Non polar
- If difference between two atom is less than 0.9, Bond will be Non polar
- If difference between two atom is between 0.9 and 1.7, Bond will be Polar with some ionic character
- If difference between two atom is greater than 1.7, Bond will be Ionic character
- The dipole moment of water is $1.84D$
- Cystine (sulphur containing) $\rightarrow$ hairs
- Disulphide bond (alpha covalent bond) stronger than hydrogen bond

Sigma (σ) bond

1. It is formed by *end to end* overlapping of half filled atomic orbitals.
2. Overlapping takes place along internuclear axis.
3. The extent of overlapping is large and bond formed is *stronger*.
4. The molecular orbital formed as a result of overlapping is symmetrical about the internuclear axis.
5. There is free rotation about σ bond and no geometrical isomers are possible.
6. The bond can be present alone.
7. *s* and *p* orbitals can participate in the formation of σ bond.

Pi (π) Bond

1. It is formed by the sidewise overlapping of half filled *p*-orbitals only.
2. Overlapping takes place perpendicular to internuclear axis.
3. The extent of overlapping is small and bond formed is *weaker*.
4. The molecular orbital formed as a result of overlapping consists of two lobes above and below the internuclear axis.
5. There is no free rotation about π bond and geometrical isomers are possible.
6. The bond is always formed in addition to sigma (σ) bond.
7. Only *p*-orbitals participate in the formation of π bond.

Chap No.4 GASES

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \cdot \frac{5}{9}$$

$$^{\circ}\text{F} = \frac{9}{5}^{\circ}\text{C} + 32$$

$$\text{K} = ^{\circ}\text{C} + 273$$

Gases

- Liquid natural gas $\rightarrow$ vehicles
- Liquid oxygen $\rightarrow$ patients

- Liquid nitrogen $\rightarrow$ dermatologists
- Liquefaction of air $\rightarrow$ to obtain gases
- Liquid Helium below 2.17 K $\rightarrow$ zero viscosity and climbing the wall of vessel

Kinetic molecular theory of gas

- Small size of gas molecule
- Negligible attractive forces
- K.E is directly proportional to absolute Temperature
- No effect of force of gravity on gas molecule
- Kinetic molecular theory of gases are proposed by Bernoulli

Pressure and its unit

- Apparatus used for measuring gas pressure is called Manometer
- Manometer used for measuring atmospheric pressure is called Barometer
- A common type of Barometer is Torricellian barometer
- $1 \text{ atm} = 760 \text{ mm Hg} = 760 \text{ torr} = 101325 \text{ Pa} = 1 \text{ Nm}^{-2} = 14.7 \text{ psi}$

Ideal Gas Laws

Boyle's law	Charles law	Avogadro's law
$V \propto 1/P$	$V \propto T$	$V \propto n$
$PV = K$	$V/T = K$	$V/n = K$
$P_1 V_1 = P_2 V_2$	$V_1/T_1 = V_2/T_2$	$V_1/n_1 = V_2/n_2$
Curve line graph	Straight line	Straight line

Graphical representation of Boyle's law
Hyperbola

Absolute Zero

- New volume at 50°C = Original volume at 0°C $+ (1/273 \times \text{Original volume at } 0^\circ \text{C}) \times 50$
- New volume at $x^\circ \text{C} = y + (y/273) \times x$
- $Y \rightarrow$ volume at 0°C
- Gas density is 10^{-3} times less than solid and liquid

Density of

- Oxygen gas $\rightarrow 0.00142 \text{ g cm}^{-3}$
- Oxygen liquid $\rightarrow 1.149 \text{ g cm}^{-3}$
- Oxygen solid $\rightarrow 1.426 \text{ g cm}^{-3}$

Ideal gas equation

- $PV = nRT$ (general gas equation or ideal gas equation)
- $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ (generalized form of ideal gas equation)
- Density $\rightarrow PV = nRT \rightarrow PV = mRT/M \rightarrow PM = RTM/V \rightarrow PM = RTd \rightarrow d = PM/RT$
- Mass $\rightarrow PV = nRT \rightarrow PV = mRT/M \rightarrow m = PVM/RT$

$\rightarrow$ When $V = 22.4 \text{ dm}^3$ and $T = 273 \text{ K}$ then unit of R

- $R = 0.0821 \text{ dm}^3 \text{ atm mole}^{-1} \text{ K}^{-1}$
- $R = 62.4 \text{ dm}^3 \text{ mm of Hg mole}^{-1} \text{ K}^{-1}$
- $R = 62.4 \text{ dm}^3 \text{ torr mole}^{-1} \text{ K}^{-1}$
- $R = 62400 \text{ cm}^3 \text{ atm mole}^{-1} \text{ K}^{-1}$

$\rightarrow$ For SI unit.

When $P = 101325 \text{ N m}^{-2}$, $V = 0.0224 \text{ m}^3$ and $T = 273 \text{ K}$ then unit of R

- $R = 8.1343 \text{ Nm mole}^{-1} \text{ K}^{-1}$
- $R = 8.1343 \text{ J mole}^{-1} \text{ K}^{-1}$
- $R = 1.98722 \text{ cal mole}^{-1} \text{ K}^{-1}$

Remember

- $1 \text{ cal} = 4.184 \text{ J}$
- 1 dm^3 of H_2 weights 0.0899 g
- 1 dm^3 of O_2 weights 1.4384 g

Ideal and Non ideal gases

- Compressibility factor $= Z = PV/nRT = 1$ (for ideal gas)
- For ideal gas plot for PV/nRT against P is parallel to x-axis

Graph of PV/nRT against P

$\rightarrow$ at 0°C

- $\text{H}_2 \rightarrow$ increase
- $\text{N}_2 \rightarrow$ little decrease then increase
- $\text{CO}_2 \rightarrow$ little more decrease then increase

$\rightarrow$ at 100°C

- $\text{H}_2 \rightarrow$ increase
- $\text{N}_2 \rightarrow$ little more decrease from that of 17°C then increase
- $\text{CO}_2 \rightarrow$ very more decrease from that of 17°C decrease then increase
- Deviation from laws occurs at Low T and high P
- One molecule is 300 times of its diameter far from another molecule

Van der waal's Equation;

- Ideal gas equation $\rightarrow PV = nRT$
- Real gas equation $\rightarrow (P + a/V^2)(V - b) = RT \rightarrow n=1$
- $(P + an^2/V^2)(V - b) = RT \rightarrow n=1$

Dalton law of partial pressure;

- $P_t = P_1 + P_2 + P_3 + P_4 + \dots + P_n$ Dalton's law of partial pressure

Graham's law of diffusion of gases

- This law relates the rate of diffusion or effusion of gases.
- Rate is inversely proportional to the density and also to the molar mass.

- $r_1 = 1/\sqrt{d_1}$
- $r_1 = 1/\sqrt{M_1}$
- $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$
- $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$
- In hydrogen and carbon dioxide the gas that will diffuse more will hydrogen because it has less molar mass, lesser the molar mass, greater will be the diffusion.

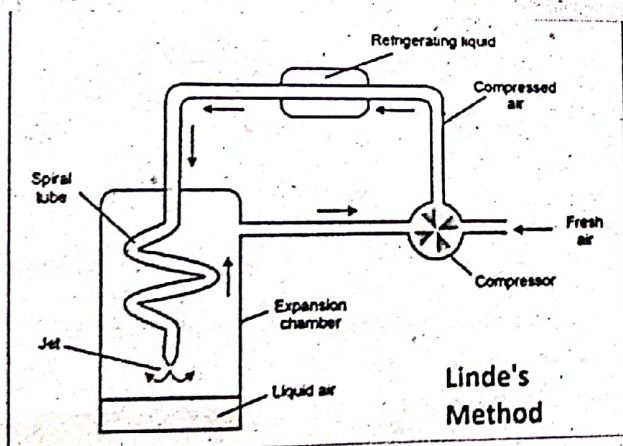
Liquefaction of gases

- The conversion of gas into liquid state by combined efforts of low temperature and high pressure is called liquefaction.
- The temperature at which gas cannot be liquefied by pressure alone is called critical temperature (T_c), while the pressure at critical temperature is called critical pressures (P_c).
- The volume occupied by gas at critical temperature and critical pressure is called critical volume (V_c).

Joule Thomson effect

- The methods of liquefaction of gases are based upon Joule Thomson effect.
- When compressed gas is allowed to expand suddenly, it produces cooling, this is called Joule Thomson effect.

Linde's Method



- Pressure 200 atm

- Based on Joule Thomson effect
- Refrigerating liquid to cool the air

Plasma

- 99% universe is made of plasma
- 1.5 million ball of plasma in sun
- Macroscopically neutral
- Electrically conductive
- Mixture of neutral particles, positive ions and negative electrons.
- When electric current is passed through neon gas it produces both plasma and light.
- Color of plasma depends upon gas used
- Evaporation occurs at all temperature

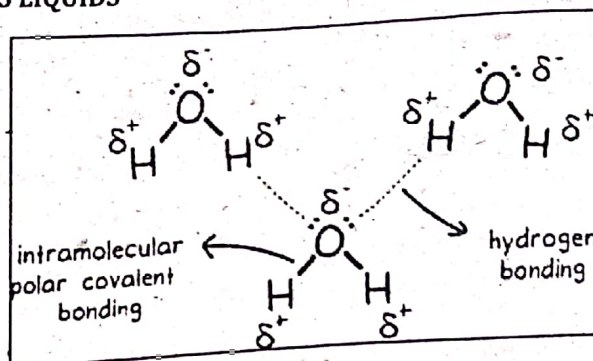
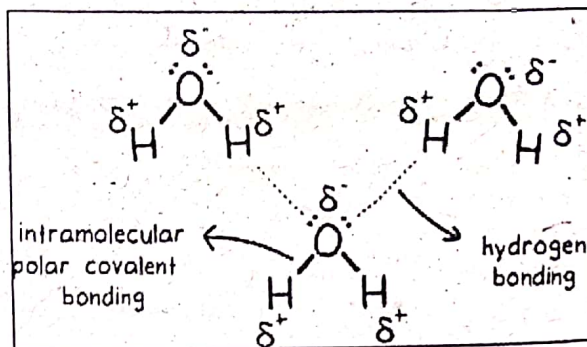
Uses of plasma

- Fluorescent bulb
- Sterilization
- Lamps
- Lasers
- Diamonds
- Microwave sources
- Computers
- Electronic equipments.

Gas Law Formula

Gas Law	Formula	Description
Boyle's Law	$P_1V_1 = P_2V_2$	At constant T , as pressure increases, volume decreases.
Charles' Law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	At constant P , as volume increases, temperature increases.
Gay-Lussac's Law	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	At constant V , as pressure increases, temperature increases.
Combined Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	Obtained by combining Boyle's Law, Charles' Law and Gay-Lussac's Law.
Ideal Gas Law	$PV = nRT$	

Chap No.5 LIQUIDS



- The state of matter which has definite volume but no definite shape is called liquid.

Kinetic molecular interpretation of Liquids

- Kinetic energy of liquid is greater than solid and lesser than gas.
- Intermolecular forces are stronger than the gas but weaker than the solids.
- Empty spaces are negligible.
- No definite shape but molecules can slide over each other.

Properties of liquids

- Definite volume
- Indefinite shape
- Diffusion
- Incompressibility
- Fluidity
- Evaporation → liquids evaporate at all temperatures.

Properties of Hydrogen Bonding

- 20 times weaker than covalent bond
- HF is weaker acid than HCl, HBr, HI
- Ethyl alcohol is miscible in water in all proportion
- Sticky action of glue and honey is due to H-bonding
- Ice has less density than water

Intramolecular forces:

(Forces within molecules)

- Covalent Bond
- Coordinate Covalent Bond

Intermolecular Forces

- Hydrogen Bonding (H and F, O, N) (present in H_2O)
- Dipole-Dipole Forces (present in HCl, HBr, H_2S)
→ stronger the dipole forces, greater the value of thermodynamic properties like melting

point, boiling point, heat of vaporization and heat of sublimation.

- London Dispersion Forces (also called dipole induced dipole interaction)
→ present in all molecules whether polar or non-polar.
→ present in monoatomic gases.
→ London dispersion forces increase with increase in size.
→ shapes of molecule also effect the strength of London dispersion forces, straight chain have larger dispersion forces than branch chain.

Covalent > Hydrogen > dipole-dipole → London dispersion

CH_3F → polar → dipole-dipole → B.P 194.7 K

C_2H_6 → non-polar → London dispersion → B.P 184.5 K

$CHCl_3$ → polar → dipole-dipole → 76.8 °C

CCl_4 → non-polar → London-dispersion → 61.2 °C

B.P ∝ size	Straight > branch
Neon → -245.9 °C	Butane → 272.5 °C
Xenon → -107.1 °C	2-Methyl propane → 261.3 °C
Fourine → gas → -188.1 °C	
Iodine → solid → 184.4 °C	

Evaporation at constant temperature, evaporation continues at the same rate

Factors affecting evaporation

- Surface area → directly
- Temperature → directly
- IMF → inversely
- Evaporation of water is slower than ether

Vapour pressure

- Pressure exerted by vapours when it is in equilibrium with liquid

Factors affecting vapour pressure

IMF → inversely

- a. Water is 24 mm of Hg at 25°C
- b. Ether is 537 mm of Hg at 25°C
- Temperature → directly
 - a. Water at 25°C is 24 mm of Hg
 - b. Water at 50°C is 93 mm of Hg
 - c. Water at 80°C is 355 mm of Hg
 - d. Water at 100°C is 760 mm of H

Measurement of vapour pressure

- Volumetric method
- Manometric method → $V.P = P + \Delta h$

Boiling point

- At B.P. K.E of molecule become maximum
- Temperature remains constant at B.P

Factors affecting boiling point

- IMF → directly
- External pressure → varies with external pressure

Place	Pressure (atm)	B.P(K)
Sea level	1	373
Muree hills	0.921	371
Mount Everest	0.425	345

Application of B.P

- Pressure cooking, an example of increased pressure: More pressure, more heat absorbed, cook quickly
- Vacuum distillation, an example of reduced pressure

At atmospheric pressure, B.P of

- $CS_2 \rightarrow 46.30^\circ C$
- $Cl_4 \rightarrow 76.50^\circ C$
- $C_2H_5OH \rightarrow 78.26^\circ C$
- $C_6H_6 \rightarrow 80.15^\circ C$
- $H_2O \rightarrow 100^\circ C$
- $CH_3COOH \rightarrow 118.50^\circ C$

- Normal pressure → glycerine boils at 290°C
- Reduced pressure → glycerine boils at 210 °C

Advantage of vacuum distillation

- Reduce time for distillation
- Avoid thermal decomposition
- Molar heat of fusion, $\Delta H_f \rightarrow$ for ice is 6 KJ/mol
- Molar heat of vaporization, $\Delta H_{vap} \rightarrow$ for water is 40.7 KJ/mol

- Molar heat of sublimation, $\Delta H_{sub} \rightarrow$ for one mole iodine 62.3 KJ/mol
- Polar molecules have higher values of molar heat, such as H_2O , SO_2 and NH_3 .

Liquid surface tension

- Amount of energy required to expand the surface of liquid by unit area.
- Unit is Jm^{-2} or Nm^{-1} .
- Surface tension decrease with increase in temperature.

Measurement of surface tension

- Torsion method
- Capillary method
- Drop method or stalagmometer meter
- Surface tension = $\gamma_l = (n_w d_l / n_l d_w) \times \gamma_w$

Viscosity

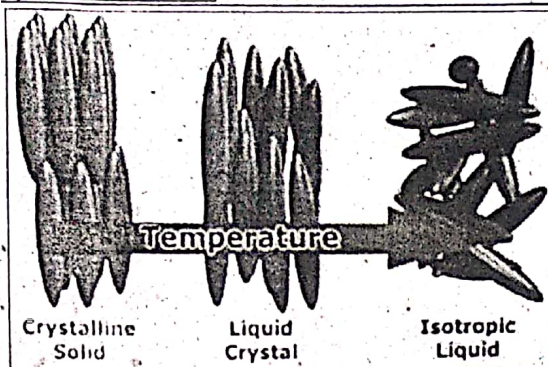
- Viscosity near sides → high
- Velocity near sides → low
- Centre → high velocity
- Centre → low viscosity

Factors affecting viscosity

- Molecular size → directly
- Molecular shape → irregular > regular shape
- IMF → directly
- Temperature → inversely
- Viscosity = $\eta_l = (d_l t_l / d_w t_w) \times \eta_w$
- Molten sulphur at 140°C with ring shape S_8 is less viscous than long chain S_n molecule at 190°C
- Viscosity of water is more than alcohol due to stronger hydrogen bonding.
- SI unit = kg/ms
- 1 poise = 0.1 kg/ms
- Water = 1 centipoise at 25°C

Liquid crystal

- Optical properties like crystalline solids
- Surface tension and viscosity like liquid
- Anisotropic optical behavior of solids
- Stearin between 52.1°C and 62.6°C
- Cholesteryl benzoate between 145°C and 179°C



- $\text{H}_2\text{O} \rightarrow 2\text{H} + \text{O} \quad \Delta H = 920 \text{ kJ/mol}$
- $\text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{O(g)} \quad \Delta H = 40.7 \text{ kJ/mol}$
- Sodium iodide $\rightarrow$ goiter
- Table salt $\rightarrow$ food

Cohesive forces among various liquids

- In water due to hydrogen bond.
- In molten metals due to metallic bond.
- In molten electrolyte due to ionic forces.
- In ionic liquid, due to Vander Waal forces.

Endothermic processes

- Solid $\rightarrow$ liquid [fusion or melting]
- Liquid $\rightarrow$ gas [vaporization]
- Solid $\rightarrow$ gas [sublimation]
- Gas $\rightarrow$ plasma [ionization]

Exothermic processes

- Liquid $\rightarrow$ solid [freezing]
- Gas $\rightarrow$ Liquid [condensation]
- Gas $\rightarrow$ Solid [Deposition]
- Plasma $\rightarrow$ Gas [Recombination or Deionization]

- $(\Delta_{\text{sub}}) > (\Delta_{\text{vap}}) > (\Delta_{\text{fus}})$
- Potassium permanganate $\rightarrow$ disinfectant
- Velocity of NH_3 /velocity of $\text{HCl} = 1.5$
- Rate of diffusion of NH_3 /Rate of diffusion of $\text{HCl} = 1.5$
- The temperature above which a gas can not be liquefied by pressure alone is called Critical temperature (T_c)
- Pressure at critical temperature is Critical Pressure (P_c)
- The volume occupied by one mole of a gas at T_c and P_c is Critical Volume (V_c)
- $\text{H}_2\text{O} \rightarrow 2\text{H} + \text{O} \quad \Delta H = 920 \text{ kJ/mol}$
- $\text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{O(g)} \quad \Delta H = 40.7 \text{ kJ/mol}$
- Intramolecular forces are stronger than Intermolecular forces
- Covalent bond, Co-ordinate covalent bond Intermolecular forces
- Hydrogen bond $>$ Dipole-Dipole interaction $>$ London dispersion forces Intermolecular forces or

- Van der Waal's forces
- Thermodynamic properties (Boiling point, Boiling point, heat of vaporization and heat of sublimation) depends upon Dipole-dipole forces
- Hydrogen bond is present between hydrogen and F, O And N
- HF is weaker acid than HCl, HBr and HI
- Ethyl alcohol ($\text{C}_2\text{H}_5\text{OH}$) is miscible in water in All proportion
- London dispersion forces (short-range forces) are also called Dipole-induced dipole interaction
- London forces are present in Polar and Non polar
- The strength of London forces depends upon Size of electronic clouds
- The boiling point increase down the group from Helium to radon
- Boiling point of neon -245.90°C
- Boiling point of xenon -107.10°C
- Boiling point of neon is less than xenon because neon has Smaller size than xenon
- Boiling point of fluorine -188.10°C
- Boiling point of iodine 184.40°C
- Boiling point of fluorine is less than iodine because fluorine has Smaller size than iodine
- Butane (C_4H_{10}) has linear structure and long chain compound its boiling point is 272.5°C
- 2-Methyl propane (C_4H_{10}) has branched structure and short chain compound its boiling point is 261.3°C
- Ethane (C_2H_6) is non-polar and its boiling point is 184.5°C (London forces)
- Fluoro-methane (CH_3F) is polar and its boiling point is 194.7°C (dipole-dipole interaction)
- Carbon tetrachloride (CCl_4) is non-polar and its boiling point is 61.20°C (London forces)
- Trichloro-methane (CHCl_3) is polar and its boiling point is 76.80°C (dipole-dipole interaction)
- Rate of evaporation of water is slower than Ether
- Vapour pressure of ether 250°C
- $V.P = P + \Delta h$
- The temperature at which vapour pressure of liquid becomes equal to atmospheric pressure is called Boiling point
- The pressure exerted by the vapours in equilibrium with a liquid at a given temperature is called Vapour pressure
- Glycerine boils at 2900°C
- Glycerine decrease to 2100°C at 50 mm of Hg
- At higher altitude, atmospheric pressure is Less than 1 atm
- Water boils at lower temperature at Higher altitude
- The amount of heat absorbed when one mole of solid converted into liquid at its melting point is called Molar heat of fusion (ΔH_f)
- Molar heat of fusion (ΔH_f) for ice is 6 kJ mol^{-1}

- The amount of heat absorbed when one mole of liquid converted into vapours at its boiling point is called Molar heat of vaporization (ΔH_{vap})
- Molar heat of vaporization (ΔH_{vap}) for water is 40.7 kJ mol^{-1}
- The amount of heat absorbed when one mole of solid is directly converted into vapours at constant temperature and 1 atm pressure is called Molar heat of sublimation (ΔH_{sub})
- Molar heat of sublimation (ΔH_{sub}) for solid iodine (I_2) is 62.3 kJ mol^{-1}
- Enthalpy change is a Physical change
- At boiling point the temperature becomes Constant
- Polar substances has higher values of ΔH_f , ΔH_{vap} , And ΔH_{sub}
- To measure surface tension we use Stalagmometer
- The layers at the center of tube of liquids have high Velocity
- The resistance of fluid to its flow is called Viscosity
- Molten sulphur at 2400°C with ring shape S_8 molecules are less viscous than long chain entangled S_n molecules at 1900°C
- The viscosity of water (H_2O) is more than ethyl-alcohol due to Hydrogen bonding of water (H_2O)
- The ratio of viscosity of liquid to the viscosity of water taken as standard is called Relative viscosity
- Viscosity (η) = $\frac{F}{A \cdot \frac{dv}{dr}}$ here d is Density
- The viscosity of water is taken as 1 Centipoise at 250°C
- To measure the relative viscosity of liquid, we use Ostwald's Viscometer
- The force required to maintain a difference of velocity of 1 ms^{-1} between two parallel layers of liquid one meter apart Co-efficient of Viscosity (η)
- The unit of Co-efficient of Viscosity (η) is $\text{Kg m}^{-1} \text{s}^{-1}$
- 1 poise = $10^{-1} \text{ Kg m}^{-1} \text{s}^{-1}$
- Stearin from 52.10°C to 62.60°C behaves like a Liquid crystal
- Cholesteryl benzoate from 145°C to 179°C behaves like a Liquid crystal
- Intramolecular forces $\rightarrow$ within molecule
- covalent bond
- coordinate covalent bond
- Intermolecular forces $\rightarrow$ among molecules $\rightarrow$ Van der Waal's forces
- hydrogen bonding $\rightarrow$ H-F, O, N
- dipole-dipole interaction $\rightarrow$ polar
- London dispersion Forces (dipole-induced dipole interaction) $\rightarrow$ polar + non polar $\rightarrow$ short range forces

Chap No.6 SOLIDS

Types	Constituent particles	Nature of forces	Melting point	Bond energy (kJ/mol)	conductivity	Examples
Ionic	Cations and anions	Ionic	Very high	400-4000	Conductor	$\text{NaCl}, \text{CaO}, \text{KNO}_3$
Covalent	Atoms	Covalent	Extremely high	150-500	Insulators	Diamond, SiO_2 , SiO_2 , silicon, crystal
Molecular	Molecules	Vander waal	Lowest	Low	Insulators	I_2 , S_8 , ice, dry ice
Metallic	Atoms	Metallic bond	High	80-1000	Conductors	$\text{Cu}, \text{Au}, \text{Ag}$ alloys

Solid and its types

Types of solids

- Crystalline / true solids
- Amorphous solids/ super cooled liquids

Crystalline solids are also called True solids

- Amorphous solids are also called Super cooled liquids
- Crystalline solids have definite Geometrical shape and their particles are Arranged properly

- Amorphous solids have no definite shape and its particles are packed together without Proper arrangement
- $\text{NaCl}, \text{CaCO}_3, \text{CaO}, \text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, Graphite and Diamond etc are Crystalline solids
- Glasses, Plastics, Rubber, Coal, Tar and Gemstone are Amorphous solids

Amorphous solids are made by silicates fusing with

- Borax oxide
- Aluminium oxide
- Phosphorous pentaoxide

Properties of crystalline solids

- Symmetry
 - Plane of symmetry > 1
 - Axis of symmetry > 1
 - Centre of symmetry = 1
- Geometric shape
- Melting point
- Cleavage plane
- Habit of crystal
- Crystal growth
- Anisotropy

Symmetry

- Plane of symmetry can be More than 1
- Axis of symmetry can be More than 1
- Centre of symmetry can be Only 1

Geometrical shape

- Grinding to a very fine powder, crystalline solids still retain their specific Geometrical shape

Melting point

- The temperature of crystalline solids remain constant until all particles become mobile

Cleavage plane

- The magnitude of interfacial angles after cleavage has taken place is always Different for different solids

Habit of crystal

- NaCl has a Cubic Habit

Crystal Growth

- NaCl will grow in one dimension (needle like) if % of urea present is 10%
- Crystalline solids have anisotropic behavior because of Regular particles arrangement

Isomorphism

NaCl - MgO	Cubic structure
ZnO - CdS	Hexagonal
KNO ₃ - NaNO ₃ - CaCO ₃	Rhombohedral

- Physical properties of isomorphs are Different from each other
- Existence of more than two compounds in one crystalline form Isomorphism

Polymorphism

- Existence of one compound in more than one crystalline form Polymorphism

KNO ₃ - AgNO ₃	Rhombohedral + orthorhombic
--------------------------------------	-----------------------------

CaCO₃

Trigonal + orthorhombic

Allotropy

- Existence of one element in more than one crystalline form Allotropy
- Sulphur exist in two allotropic forms Rhombohedral and monoclinic

Sulphur	Rhombohedral and monoclinic
Oxygen	O ₂ and O ₃
Carbon	Diamond, graphite and bucky balls
Tin	Grey fine cubic and white tin tetragonal

Transition Temperature

- The temperature at which one crystalline form changes to another Transition Temperature
- Crystalline forms of same substance coexist in equilibrium at Transition Temperature

Sulphur	95.5 °C
Tin	13.2 °C
KON ₃	128.5 °C

Crystal lattice

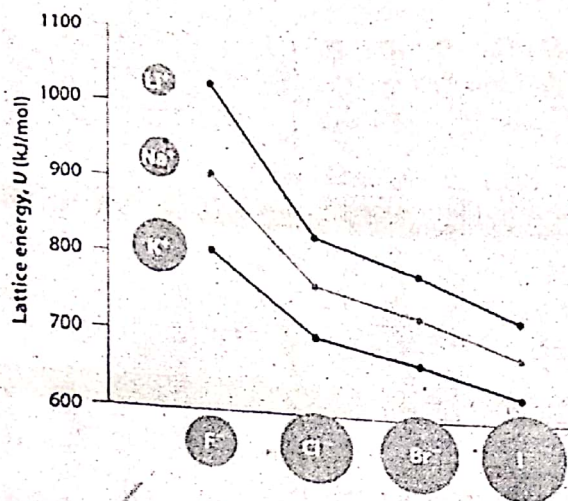
- 3D arrangement of particles in solid → lattice
- $\alpha, \beta, \gamma, a, b, c$ are unit cell dimensions or Crystallographic elements
- Six parameters = 3 edges + e angles
- Cubic lattices
- Simple cubic lattice → p type
- Body center cubic → l type
- Face center cubic → f type
- In NaCl, Na is attracted by 6 Cl and Cl is attracted by 6 Na

Lattice energy

- Energy required(+) to break one mole ionic crystal to its ions in the gas phase or energy released(-) when one mole of ionic crystal is formed from its opposite gaseous atoms
- Lattice energy $\propto$ charge of ion
- Lattice energy $\propto \frac{1}{\text{size of ion}}$
- Joining both equations
- Lattice energy $\propto \frac{\text{charge of ions}}{\text{size of ion}}$
- Lattice energy $\propto \frac{q^+q^-}{r^+r^-}$

Lattice energy for

- NaF is 895 kJ mol⁻¹
- NaCl is 787 kJ mol⁻¹
- NaBr is 728 kJ mol⁻¹

NaI is 690 kJ mol⁻¹

Lattice energy (for ionic substances) depends upon

- as the charge of the ions increases, the lattice energy increases
- as the size of the ions increases, the lattice energy decreases

Compound	Name:	Charge on each ion	Lattice energy (kJ/mol)
NaCl	sodium chloride	1, -1	-787.5
NaBr	sodium bromide	1, -1	-751.4
CaF ₂	calcium fluoride	+2, -1	-2634.7
MgO	magnesium oxide	+2, -2	-3760

Types of crystalline solids

Ionic crystal	Long range, Never exist in liquid or gas, Soluble in polar, NaCl, MgO, NaBr
Metallic crystal	Malleable → sheets, Ductile → wires, Only few are soft,

	Copper, iron, aluminium, sodium, silver
Covalent crystal	insoluble in polar Diamond, carborundum, silicon carbide
Molecular crystal	Tightly packed patterns Soft May be: Polar (sugar and ice) or Non-polar (solidified noble gas, CO ₂ , S, P and I)

- NaCl, MgO and NaBr are Ionic crystals
- Diamond, Carborundum and Silicon carbide are Covalent crystals
- Copper, Aluminium, Silver, Iron and Sodium are Metallic crystals
- Ice and Sugar are Polar molecular crystals
- Carbon dioxide, Sulphur, Phosphorus, Solidified noble gases and Iodine are Non-polar molecular crystals
- The melting point of Ionic crystals, Covalent crystals, Metallic crystals are high while Molecular crystals have High melting point
- The Ionic crystals, Covalent crystals, Metallic crystals are hard while Molecular crystals are Soft
- The Ionic crystals are soluble in Polar
- The Covalent crystals are soluble in Non-polar
- The Molecular crystals are soluble in Non-polar
- Ionic crystals are Do not conduct heat and electricity
- Covalent crystals are Poor conductors of heat and electricity
- Metallic crystals are Good conductors of heat and electricity
- Metallic crystals Ductile and Malleable
- Because of the polar nature of molecule and presence of strong hydrogen bonding, ice has high value of Heat of fusion
- Molecular crystals are soft and have low melting points.
- Ionic, covalent and metallic crystals are hard and have high m.p

Chap No.7 CHEMICAL EQUILIBRIUM

Law of mass action

- The law of mass action was proposed by C.M. Guldberg and P. Waage in 1864
- Mathematical representation of law of mass action $K_c = \frac{[C]^2[D]^2}{[A]^2[B]^2}$

- The product concentration is much greater than reactants at equilibrium if K_c is very large.
- The value of K_c is independent of initial and final concentrations.
- The value of K_c change with change in temperature.

Realation between Kp, Kc and Kn

- The relationship between Kp and Kc is $K_p = K_c (RT)^{\Delta n}$
 - $\Delta n = n_p - n_r$
 - $K_p \propto \Delta n$
 - If $\Delta n = 0$, $K_p = K_c$
 - If $\Delta n = \text{positive}$, $K_p > K_c$
 - If $\Delta n = \text{negative}$, $K_p < K_c$
- The relationship between Kp and Kx is $K_p = K_x (P)^{\Delta n}$
 - $\Delta n = n_p - n_r$
 - If $\Delta n = 0$, $K_p = K_x$
 - If $\Delta n = \text{positive}$, $K_p > K_x$
 - If $\Delta n = \text{negative}$, $K_p < K_x$
- The relationship between Kp and Kn is $K_p = K_n (P/N)^{\Delta n}$
 - $\Delta n = n_p - n_r$
 - If $\Delta n = 0$, $K_p = K_n$
 - If $\Delta n = \text{positive}$, $K_p > K_n$
 - If $\Delta n = \text{negative}$, $K_p < K_n$
- If $\Delta n = 0$ then the relationship between Kp, Kc, Kx and Kn is $K_p = K_x = K_c = K_n$

Unit of Kp and Kc

- If number of product = number of reactants, then Kp and Kc has no units.
- If number of product $\neq$ number of reactants, then Kp and Kc has units.
- $2SO_2 + O_2 \rightleftharpoons 2SO_3$

$$K_c = \frac{[SO_3]^2}{[SO_2]^2 [O_2]} = \frac{[mol/dm^{-3}]^2}{[mol/dm^{-3}]^2 [mol/dm^{-3}]} = \frac{1}{mol/dm^{-3}} = mol/dm^3$$

$$K_p = 1/atm = atm^{-1}$$

Formula for concentration

- $N_2 + 3H_2 \rightleftharpoons 2NH_3$
 - If initial concentratin were a and b for that of nitrogen and hydrogen
 - $N_2 + 3H_2 \rightleftharpoons 2NH_3$
 - Initially $\rightarrow a \quad b \quad 0$
 - Equi $\rightarrow a-x \quad b-x \quad 2x$
- $$K_c = \frac{2x^2}{(a-x)(b-x)^3} = \frac{2x^2}{(a-x)(b-x)^3}$$

Reaction Quotient Qc

- The reaction is at equilibrium if $Q_c = K_c$
- Forward reaction will occur if $Q_c < K_c$
- Backward reaction will occur if $Q_c > K_c$

Prediction of chemical reaction

- K_c very large $\rightarrow$ reaction almost complete
- K_c very small $\rightarrow$ small product is formed
- K_c neither small or large $\rightarrow$ appreciable quantities
- K_c is independent to initial concentrations.
- K_c change with change in temperature.

Optimum temperature for the formation of

- $NO_2 \rightarrow 3000^\circ C$
- $NH_3 \rightarrow 450^\circ C$
- $SO_3 \rightarrow 400-500^\circ C$ and 1.5-1.7 atm

Le Chatliet's Principle:

- If system at equiulibrium is subjected to stress by change in tmperature, pressure and concentration, the system will tends to adjust itself so as t minimize the effect of that change.

Effect of change in concentration

- The addition of reation will cause increase in rate of reaction.
- Removing of product will cause more reaction to occur.

Effecct on change in pressure

- If pressure is deacresed, the reaction will move in such direcio to deecreas the volume.
- For reaction of such as equal reactant forms equal volume of product, then this reaction will not be effected by change inpressure like $2HI$ gives H_2 and I_2 as 2 mol Hi give one mole of h and one mole of I so 2 moles reactant gives 2 mole products.

Effect of change intmperature:

- For edothermic process, greater product will be obtained by increased in temperatue.
- For exothermic process, greater product will beobtained by decreaseing temperature.

Catalyst effect:

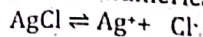
- Catalyst does not effect the peed of formationof product beacause it just increase the speed at both directions.

Solubility product (K_{sp})

- $K_{sp} \propto$ solubility
- Solubility product (K_{sp}) is dependent to Temperature
- At room temperature solubility product (K_{sp}) is Very small
- product of molar concentrations of its ions in the saturated solution
- usually very small at room temperature

- Temperature dependent

Solution of numericals on K_{sp} e.g.

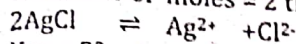


no. of moles: 1 1 1

No of moles x x x

$$K_{sp} = x^2$$

If number of moles = 2 then like



$$K_{sp} = 2^2 = 4$$

- Ionic product $> K_{sp} \rightarrow$ super saturated
- Ionic product $< K_{sp} \rightarrow$ unsaturated solution

Common ion effect

- NH_4Cl suppresses NH_4OH
- HCl suppresses NaCl
- Addition NH_4Cl of suppresses the ionization of NH_4OH
- Addition HCl of suppresses the ionization of NaCl
- Acids $\rightarrow$ sour taste
- Reaction with metal oxides, hydroxides and carbonates and metals to form salts.

Haber Process:

- Production of ammonia is called Haber processes.
- Its an exothermic processes
- 46kj energy is evolved.

Ionic product

- product of molar concentrations of its ions in the saturated solution at particular solution.
- Ionic product = $K_{sp} \rightarrow$ saturated solution in equilibrium with excess solid

Chap No.8 ACIDS, BASES AND SALTS

- Acids are organized by sour taste.
- Acids are also recognized by reacting with metal oxide, hydroxide and carbonate. All of this reaction produce ionic compounds called salts.
- If a base dissolves in water it is called an Alkali
- $pK_w = 14$ at 250 C. the value pK_w of decrease with Increase in temperature
- HCl is strong acid so its K_a value is very large ($10+7$) and its pK_a value is Small (-7)
- Ag^+ , AlCl_3 are Lewis acid
- $pK_a + pK_b = 14$
- PH of water is 7.4 and it is Buffer solution
- $\text{PH} = pK_a + \log \frac{[A^-]}{[HA]}$ or $\text{PH} = pK_a + \log \frac{[\text{salt}]}{[\text{acid}]}$ is called Henderson-Hasselbalch equation
- Bases $\rightarrow$ slimy feel

Concepts of acid and bases

Concept	Acids	Bases
Arhenius	Loss H	Loss OH
Bronsted-lowry	Loss H (HCl)	Gain H (NH_3)
Lewis	Gain es pair	Loss es pair

Lewis acids:	Lewis bases:
✓ NO_2	✓ NH_3
✓ H_3O^+	✓ H_2O
✓ Cl^+	✓ CO

✓ SO_3H ✓ BF_3 ✓ AlCl_3 ✓ SO_2 ✓ CO_2	✓ $\text{C}\equiv\text{N}$ ✓ ROR ✓ ROH ✓ RNH_2 ✓ OH^- ✓ Cl^- ✓ CO_3^{2-} ✓ SO_4^{2-}
• Strong Acids: ✓ H_2SO_4 ✓ HCl ✓ HNO_3 ✓ HBr ✓ HI ✓ HClO_3 ✓ HClO_4	• Amphoteric substances; ✓ H_2O ✓ HCO_3^- ✓ HSO_4^- • Weak acids ✓ H_2CO_3 ✓ CH_3COOH ✓ HNO_2 ✓ H_2S ✓ HCOOH
• Strong bases: ✓ NaOH ✓ KOH ✓ $\text{Ca}(\text{OH})_2$ ✓ HClO_4	• Weak bases: ✓ NH_4OH ✓ $\text{Cu}(\text{OH})_2$ ✓ $\text{Fe}(\text{OH})_3$ ✓ $\text{Al}(\text{OH})_3$

- Negative ions act as lewis base. A weak acid has is a Strong conjugate base

- A weak base has is a Strong conjugate acid

Conjugate Acid Base

- $\text{CH}_3\text{COOH} \rightarrow$ weak acid and CH_3COO^- is strong conjugate base
- $\text{HCl} \rightarrow$ strong acid and Cl^- is strong conjugate base.
- $\text{NH}_3 \rightarrow$ weak base and NH_4^+ is strong conjugate acid.
- $\text{H}_2\text{O} \rightarrow$ weak base and H_3O^+ is strong conjugate acid

Ionization of water;

- $[\text{H}^+][\text{OH}^-] = K_w = 10^{-14}$
- $[\text{H}^+] = [\text{OH}^-] = 10^{-7} \text{ mol/dm}^3$ neutral water.

pH, pOH and pK_w

- $\text{pH} = -\log [\text{H}^+] = -\log 10^{-7+}$
- For neutral solution $\text{pH} = 7$
- For acidic solution $\text{pH} < 7$
- For basic solution $\text{pH} > 7$
- $pK_w = -\log K_w = -\log 10^{-14} = -14(-\log 10) = 14$
- the value of pK_w decrease with increase in temperature.
- $[\text{H}^+][\text{OH}^-] = K_w = 10^{-14} \rightarrow \text{pH} + \text{pOH} = pK_w = 14$
- $[\text{H}^+][\text{OH}^-] = 10^{-14}$
- $K_a \times K_b = [\text{H}^+][\text{OH}^-] = 10^{-14}$
- $\text{pH} + \text{pOH} = pK_w = 14$
- $pK_a + pK_b = pK_w = 14$

$\text{pH}: \text{pH} \propto \text{Basidity} \quad \text{pH} \propto 1/\text{Acidity} \quad \text{pH} \propto 1/[\text{H}^+]$
 $\text{pOH}: \text{pOH} \propto \text{acidity} \quad \text{pOH} \propto 1/\text{Basidity} \quad \text{pOH} \propto 1/[\text{OH}^-]$

Acid Ionization Constant

- $\text{H}_2\text{O} + \text{HA} \rightleftharpoons \text{H}_3\text{O}^+ + \text{A}^-$
- $K_c \text{ H}_2\text{O} = [\text{H}_3\text{O}^+ + \text{A}^-] / [\text{HA}] = K_a$
- Where K_a is dissociation constant of acid. It is the ratio of the concentration of dissociated ions to the undissociated acid molecules in aqueous solution.
- Greater the value of K_a , greater the is the acid strength and vice versa.
- A negative log of K_a is called pK_a . Since it is negative of K_a , so greater the pK_a value, weaker will be the acid strength.
- $pK_a = -\log K_a$
- $K_a \propto \text{strength of an acids}$
- $pK_a \propto 1/\text{strength of acids}$

Base Ionization Constant

- $\text{A}^- + \text{H}_2\text{O} \rightleftharpoons \text{HA} + \text{OH}^-$
- $K_c = [\text{HA} + \text{OH}^-] / [\text{A}^- + \text{H}_2\text{O}]$
- $K_b = [\text{HA} + \text{OH}^-] / [\text{A}^-]$

- $pK_b = -\log K_b$
- $K_b \propto \text{strength of bases}$
- $pK_b \propto 1/\text{strength of bases}$
- Strong base have high K_b value and small pK_b value.
- $K_a \times K_b = K_w = 10^{-14}$
- $pK_a + pK_b = 14$

Acidity decrease downward
HClO_4
HI
HBr
HCl
H_2SO_4
HNO_3
HClO_3
$(\text{COOH})_2$
H_2SO_3
CH_3COOH
H_2CO_3
H_2S
NH_4^+
HCN

Levelling acid:

- It is applicable for nearly same acid strength.
- All the strong acids have same pK_a values in aqueous solution.
- Significance difference in their strength is observed when they are dissolved in **anhydrous acetic acid**.

Buffers solution is made of;

- Weak acid and its salt with strong base $\rightarrow$ pH less than 7 (acidic)
 $\text{CH}_3\text{COOH}/\text{CH}_3\text{COONa}$
- Weak base and its salt with strong acid $\rightarrow$ pH more than 7 (basic)
 $\text{NH}_4\text{OH}/\text{NH}_4\text{Cl}$

Henderson-Hasselbalch equation

- $\text{pH} = pK_a + \log \frac{\text{salt}}{\text{acid}}$
- If salt > acid, then $\text{pH} > pK_a$
- If salt < acid, then $\text{pH} < pK_a$
- Human blood is pH of 7.4 by means by
- Bicarbonates
- phosphates
- complex protein systems

Identification of acid and basic solution

If M = molarity, and V = volume

Acidic: $[\text{H}^+] \times M \times V$

Basic: $[\text{OH}^-] \times M \times V$

If $[\text{H}^+] \times M \times V$ is greater than $[\text{OH}^-] \times M \times V$ then solution is acidic.

If $[\text{H}^+] \times M \times V$ is less than $[\text{OH}^-] \times M \times V$ then solution is basic.

Salt Hydrolysis

- Salt derived from a strong acid and weak base make the solution Acidic
- Salt derived from a strong base and weak acid make the solution Basic
- Salt derived from a strong acid and strong base make the solution Neutral
- Salt derived from a weak acid and weak base make the solution Acidic, basic or neutral

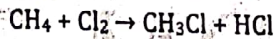
- Salt (NH_4Cl) derived from a strong acid (HCl) and weak base (NH_4OH) make the solution Acidic
- Salt (CH_3COONa) derived from a strong base (NaOH) and weak acid (CH_3COOH) make the solution Basic
- Salt (NaCl) derived from a strong acid (HCl) and strong base (NaOH) make the solution Neutral
- Salt ($\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$, NH_4CN and FeCO_3) derived from a weak acid and weak base make the solution Acidic, basic or neutral depending upon K_a and K_b value.
- The pH of solution of NH_4CN is greater than 7 because CN^- is more basic than NH_4^+ .

Acid	Base	Examples	Ions (important)	pH
Strong	Strong	NaCl , KBr	None	=7 Neutral
Strong	Weak	NH_4NO_3 , NH_4Cl	Cation NH_4^+	<7 Acidic
Weak	Strong	NaCN , K_2CO_3	Anion CN^- , CO_3^{2-}	>7 Basic
Weak	Weak	NH_4NO_2 , NH_4CN	Both cation and anion	Acidic, basic, neutral

Chap No.9 CHEMICAL KINETICS

- Increasing the concentration of reaction increase the Reaction rate
- Rate of chemical reaction is proportional to product of molar concentration to reaction substances each raise to appropriate power Rate law or Rate expression
- For $aA + bB \rightarrow \text{Products}$,
Rate = $-\Delta[A]/dt = k[A]^a[B]^b$ Here k has fixed value for a reaction at given Temperature and pressure
- unit of rate: $\text{mol/dm}^3 \text{ s}$, mol/L s , mol/s
- Sum of exponents of concentration terms in the rate expression of equation is called Order of Reactions
- 10^{32} molecules per liter per second at standard conditions Number of colliding molecules
- Decomposition reaction rate of gaseous hydrogen iodide is $4.4 \times 10^{-3} \text{ mol/dm}^3\text{-hour}$
- Decomposition reaction rate of gaseous di-nitrogen pentoxide is $9.4 \times 10^5 \text{ mol/dm}^3\text{-hour}$
- Transition is always greater than Reactants
- Rate = $k P[A]^a [B]^b$ here K is velocity or rate constant
- If a and $b = 1$ then rate = k
- K has fixed value for reaction under given T and P .

- Zero order reaction:
- rate does not depend on concentration of reactants:

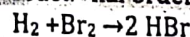


$$\text{Rate} = k [\text{CH}_4]^0 [\text{Cl}_2]^0$$

$$\text{Rate} = k$$

$$\text{Unit of } k = \text{mol/dm}^3\text{s}$$

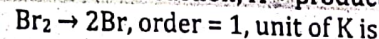
- Fractional order reaction:



$$\text{Rate} = k [\text{H}_2] [\text{Br}_2]^{1/2}, \text{ order} = 1 + 1/2 = 1.5$$

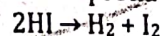
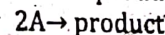
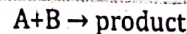
$$\text{Unit of } k = \text{rate}/(\text{conc})(\text{conc})^{1/2} = \text{mol}^{-1/2} \text{ dm}^3/2\text{s}^{-1}$$

- First order reaction; $A \rightarrow \text{product}$



$$K = \text{rate}/\text{conce} = \text{mol m}^{-3} \text{ s}^{-1} / \text{mol}^{-1} \text{ m}^{-3} = \text{s}^{-1}$$

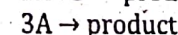
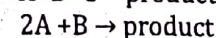
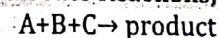
- Second order reactions:



$$\text{Rate} = k [\text{HI}]^2$$

$$\text{UNIT OF } k = \text{rate}/\text{con}^2 = \text{rate} / \text{H}^2 = \text{mol m}^{-3} \text{ s}^{-1} / (\text{mol m}^{-3})^2 = \text{mol}^{-1} \text{ m}^3 \text{ s}^{-1}$$

- Third Order Reactions;



$$\text{UNIT OF } k = \text{rate}/\text{con}^3 = \text{rate} / \text{H}^3 = \text{mol m}^{-3} \text{ s}^{-1} / (\text{mol m}^{-3})^3 = \text{mol}^{-2} \text{ m}^6 \text{ s}^{-1}$$

Order of reaction;

- When concentration double and rate does not change then it is Zero Order.
- When conc doubles and rate doubles → first order
- When conc doubles and rate quadruples → second order
- Isolation method is used to find order

- 10^{32} molecules per litre per second at standard conditions.
- Order is experimentally determined parameter

Under same STP, the decomposition rate of

- $\text{H}_2\text{O}_2 \rightarrow 4.4 \times 10^{-3} \text{ mol/dm}^3\text{-hour}$
- $\text{N}_2\text{O}_5 \rightarrow 9.4 \times 10^5 \text{ mol/dm}^3\text{-hour}$

Factors affecting rate of reaction

- Nature of reactants: different substances react differently.
- Conc of reactant; Rate of reaction increase with increase of concentration.
- Particle size of solid reacting gases; increase in surface area leads to greater reaction rate.
- Temperature: increase in reaction cause increase in rate of reaction in some cases.
- Catalyst: a reaction may be increased or decreased in some case, by the presence of catalyst.
- Decreasing order of rate of reaction: gas > liquids > solids

Transition state

- Impossible to isolate it
- It has Molecular weight
- Intermediate distance
- A definite enthalpy
- Loss structure
- Ability to rotate and vibrate
- Greater energy than reactant and product
- Remember the transition state properties specially

$$E_{\text{reactant}} < E_{\text{state}} > E_{\text{product}}$$

Theories of Reaction rate

Activation Energy;

- When molecules collides, part of their kinetic energy is converted into potential energy.
- If kinetic energy is large, then colliding molecules will vibrate so strongly as to break some of the chemical bonds.
- If the initial kinetic energy is small, the molecules will just touch each other with certain forces.
- There is minimum energy below which no reaction occurs and is called Activation energy.

Collision theory of reaction rate

- Collision with proper orientation and proper activation energy can only leads to reaction.

Catalysts

- Catalyst for hydrogen peroxide decomposition is MnO_2
- Catalyst for SO_3 is NO_2
- Catalyst for NH_3 is Fe_2O_3 or Mn_2O
- Catalyst for $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ is Ni
- Ptyalin → starch to sugar
- Pepsin → protein to simple molecules
- Sodium chloride, ammonia and potassium are Inorganic substances
- Benzene, alcohol and ether are Organic solvents
- Sugar, methanol and carboxylic acids are Organic substances

Chap No.10 SOLUTIONS AND COLLOIDS

- Sodium chloride, ammonia and potassium Inorganic substances
- Benzene, alcohol and ether Organic solvents
- Sugar, methanol and carboxylic acids Organic substances

Mixtures;

- Salt dissolved in sugar → Coarse mixture
- Clay dissolved in water → Suspension
- Gum dissolved in water → Colloidal dispersion
- Sugar dissolved in water → True solution

- At 25°C the upper layer 5% solution of phenol in water and lower layer is 30% water in phenol
- At phenol-water system critical solution is formed at 65.90°C
- Weight in grams of solute necessary to saturate 100 grams of solvent at given temperature and pressure Solubility
- At constant temperature the solubility is directly proportional to the Pressure
- Number of moles of solute/number of kg of solvent Molality (m)
- Number of moles of solute/volume of solution (dm^3) Molarity (M)

Temperature dependent and independent quantities

- solubility → Dependent
- To temperature, lowering of vapour pressure of solute dissolved in solvent is Independent
- molality → Independent
- mole friction → Independent
- Hydrophilic → water soluble → much stable → reversible colloids
- Hydrophobic → water insoluble → not stable → irreversible

Solutions of Liquids in liquids**Completely miscible**

→ vol inc or dec, separated by frictional distillation.

- Alcohol and water
- Alcohol and ether

Partially miscible

- Phenol-water system
- Tryethylamine-water system
- Nicotine water system

Completely immiscible

- Benzene and water
- Caron disulphide and water

Solubility

- Weight in grams of solute necessary to saturate 100 grams of solvent at given temperature and pressure Solubility.
- At constant temperature the solubility is directly proportional to the Pressure.

Solubility depends upon

- nature of solute and solvent
→ 100 g of water dissolves
192 g NH_4NO_3 , 6.5 g HgCl_2 and 8.4×10^{-4} g Ag Br
- → ethyl alcohol dissolves
3.8 g NH_4NO_3 , 47.6g HgCl_2
- Pressure, directly relation to pressure above the liquid.
- Temperature

unaffected	Increase with T	Dec with inc in T
NaCl KBr	KNO_3 $\text{Al}_2(\text{SO}_4)_3$ KCl, $\text{K}_2\text{SO}_4, \text{KClO}_3$	$\text{Ce}_2(\text{SO}_4)_3$ Li_2CO_3

Molarity, molality and mole fraction

- Number of moles of solute/number of kg of solvent Molality (m)
- Number of moles of solute/volume of solution (dm^3) Molarity (M)

T dependent	T independent
Molarity Solubility	Molality Mole friction $\Delta P/p$ Change in pressure

- If heat of solution inc, its endothermic and if dec its exothermic.
- Solubility inc with in T and dec with dec in T for endothermic
- Solubility dec with inc in T and vice versa for exothermic process.

Molarity (M)	Molality (m)	Mole fraction
$n/\text{vol}(\text{dm}^3)$ mol/dm^3	$n/1\text{kg solvent}$ mol/kg	$N_1/(n_1+n_2)$

Molarity = Moles of solute/Liters of Solution (M)

Molality = Moles of solute/Kg of Solvent (m)

Mole Fraction = Moles solute/total number of moles

Mass % = Mass solute/total mass x 100

Concentration units

- Parts per million (ppm) → impurities of sub = wt. or vol. of solute / wt. or vol. of solution x 10^6
- Parts per billion (ppb) = wt. or vol. of solute / wt. or vol. of solution x 10^9
- Parts per trillion (ppt) = wt. or vol. of solute / wt. or vol. of solution x 10^{12}

Colligative properties of dilute solution

- Lowering of vapour pressure → $\Delta P/P_0 = X_2 \Rightarrow n_2/n_1$
- Elevation of boiling point → $\Delta T_b = k_b m$
- Depression in freezing point → $\Delta T_f = k_f m$
- Osmotic pressure
- Elevation of boiling point → ebullioscopic constant
- Depression in freezing point → cryoscopic constant

Osmosis

- For low molecular sub membrane is $\text{Cu}_2[\text{Fe}(\text{CN})_6]$
- For high molecular sub membrane is of cellulose or cellulose nitrate
- Osmotic pressure is directly proportional to concentration, this is by Pfeffer

Hydrates

- $\text{CaSO}_4 \rightarrow$ monohydrate
- $\text{CuSO}_4 \rightarrow$ pentahydrates
- $\text{MgSO}_4 \rightarrow$ heptahydrates
- $\text{Na}_2\text{CO}_3 \rightarrow$ decahydrates

 NH_4NO_3

- freezing mixture
- electrovalent compound
- form ions in water $\rightarrow \text{NH}_4^+$ and NO_3^-
- high affinity for water like other alkali metal salts

- reason for loss and gain of heat is the inter particle attractive forces
- endothermic $\rightarrow \text{KI}$
- exothermic $\rightarrow \text{NaOH}$
- when gas is dissolved in solvent, energy is always evolved, only solute-solvent interactions are interactive.
- When neutralization reaction takes place, we get salt solution

Properties of colloids

- Optical properties
 - a. Colloid particles scatter light in all directions
 - b. Blue light scatters more
- Brownian movement
 - a. Diameter more than one micron $\rightarrow$ colloids particle get thousands of blows
 - b. Zigzag path $\rightarrow$ ultramicroscope
- Filterability $\rightarrow$ need ultrafilters
- Diffusibility $\rightarrow$ little power of diffusion
- Colour
 - a. Depends on size, shape and wave length of scatter light
 - b. Silver sols with different size show different colours

- Osmotic pressure $\rightarrow \pi = RTC/M$
Measured by osmometer
- $\rightarrow \rightarrow$ Osmotic pressure $\rightarrow \pi = RTC/M$, here R is universal gas constant.
Measured by osmometer
But for ideal solution, $\pi = MRT$
Osmotic pressure is the mechanical pressure required to prevent osmosis.
 $\pi \propto T$, here T is temperature
 $\pi \propto C$, here C is concentration
 $\pi \propto 1/M$, here m is molar mass

Effect of temperature change

- Change in temperature coagulate colloids.
- Blood clot must washed by cold water
- Casein with heating coagulates in water

Stability of colloids Depends upon

- Charge
- Solvations
- Brownian motions
- A dissolved dissolve in liquid, its vapour pressure is Decreased
- Pressure of solution is always less than Solvent pressure
- Lowering of vapour pressure depends upon nature of solvent, concentration of solute but not on Nature of solute
- The partial vapour pressure of any volatile component of solution is equal to the vapour pressure of the pure component multiplied by the mole fraction of that component of solution Raoult's Law
- Elevation of boiling point of dilute solution is directly proportional to Temperature
- Types of colloidal suspension are 8.

Chap No.11 THERMOCHEMISTRY**Energy in chemical Reactions:**

- Thermochemistry is the branch of chemistry that deals with thermal or heat changes during chemical reactions.
- The SI unit of heat and energy is joule (J).
- Heat changes associated with chemical reactions are expressed in kilojoule (kJ).

- The natural tendency of any system to go to lower energy state by itself, is called spontaneous reactions.
- Spontaneous reactions are exothermic in nature.
- Some spontaneous reactions are:
 - Flow of water from higher to lower level
 - Flow of heat from hot to cold body

- Flow of electricity from higher to lower potential
- Diffusion of gases
- Evaporation of water
- Melting of ice
- Cooling of hot tea
- Escape of steam from pressure cooker
- Burning of natural gas, (CH_4) .
- Rusting of iron, $Fe(OH)_3$.
- Changes that need external source to the system or by doing some work on the system are called non-spontaneous reactions or non-spontaneous changes.
- Non-spontaneous changes are endothermic in nature.
- Some non-spontaneous changes are:
 - Pumping of water uphill
 - Compression of gases
 - Boiling of water
 - Freezing of water
 - Water decomposition by electrolysis
- Albert Einstein in 1905 proposed his classic that matter and energy are equivalent.
- The conversion of one gram of matter to energy yields 2.2×10^{13} cal.
- The 2.2×10^{13} cal heat can raise temperature of 25,000 tone or 5×10^8 lb of water from $0^\circ C$ to $100^\circ C$.
- Energy stored in matter depends only on mass of matter and not on the characteristics of matter.
- During combustion of 3000 tons of coal only 1 g of matter is converted into energy.
- Loss of mass of coal is 3×10^{-9} g.
- The heat of reaction for spontaneous changes are written with negative sign.
- The heat of reaction for non-spontaneous reactions are written with positive sign.
- $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$
- $1 \text{ cal} = 4.184 \text{ J}$
- $1 \text{ ton} = 1000 \text{ kg}$
- $1 \text{ dm}^3 \text{ atm} = 101.25 \text{ J}$
- For bond breaking, energy must be absorbed.
- When bond forms, energy is liberated.
- ΔH per mole is expressed in the units of kJ.

Thermodynamics

- Thermodynamics deals with flow of heat or any other form of energy into or out of a system.
- A system is that part of universe which is under specific consideration.
- The universe other than system is called surrounding.
- Both system and surrounding are separated by real or imaginary surface called boundary.
- System + surrounding = Universe
- $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

- Some properties, in which the change in one property changes the state of the system, are called state variable or state function.
- A state function depends upon only on initial and final state and independent to path followed.
- Some state functions are:
 - Temperature
 - Pressure
 - Force
 - Volume
 - Internal energy
 - Enthalpy
- Some properties that are path dependant and are not state functions for example heat and work.
- Heat and work or not property they just show the mode of transfer of energy.

Internal Energy (E)

- The sum of all energies of atom is called internal energy.
- Following values cannot be determined. However, change in them can be measured and calculated:
 - Internal energy (E)
 - Enthalpy (H)
- Increase in internal energy can result:
 - Temperature increase
 - Phase change
 - Chemical reaction

First Law of Thermodynamics

- First law of thermodynamics is in fact, the law of conservation of energy.
- Law of conservation of energy states that energy can neither be created nor destroyed.
- Energy is transferred between system and surrounding in the form of heat and work.
- The first law of thermodynamics can be written as follows.
 - $q = \Delta E + w$
 - $\Delta E = q - w$
 - $\Delta E = q + w$
- the only type of work in thermodynamics is the Pv pressure-volume work.
- Work is done when a system expands.
- Work done by system and energy absorbed by system are taken as positive.
- At constant volume, no work is done.
- Heat absorbed at constant volume is used to increase the internal energy only and no work is done. $\Delta E = q$.
- Unit of work and heat is Nm or Joules (J).

Enthalpy of system and standard changes

- Enthalpy means heat content:

- The total heat content of a system at constant pressure is called enthalpy of a system.
- The enthalpy of a system is given by: $H = E + PV$
- Change in enthalpy is given by: $\Delta H = \Delta E + P \Delta V$
- Heat evolved or absorbed at constant pressure during a process or a reaction is equal to change in the enthalpy of the system.
- ΔH is positive when heat is absorbed.
- ΔH is negative when heat is evolved.
- Enthalpy for solids and liquids are $\Delta H = \Delta E$, because there is small change in volume and ΔV can be neglected.
- Standard enthalpy change, ΔH° : the change in enthalpy measured at room temperature (298K) and one atmospheric pressure when the reactants and products are in their standard or natural states is called standard enthalpy change.
- The standard enthalpy ΔH° of the elements in their standard states have given the value zero.
- ΔH° have positive values at high temperature.
- ΔH° have negative values at low temperature.
- For all solids and liquids: $\Delta H = \Delta E$.
- No work is done at constant volume.
- Pressure-volume work is form of mechanical work.

Heat Capacity

- Heat capacity depends on Mass.
- The heat absorbed to raise the temperature by one degree or one kelvin is called heat capacity.
- The SI unit of heat capacity is joule per kelvin or JK^{-1} .
- Heat capacity is expressed in two ways:
 - Specific heat
 - Molar heat capacity
- The amount of heat absorbed by one gram of substance to raise the temperature by one degree is called specific heat.
- The amount of heat required to raise the temperature of one mole of a substance through one degree or one kelvin is called molar heat capacity.

Calorimetry

- The numerical value of the enthalpy of the reaction depends on conditions, the pressure and the temperature under which the reaction takes place.
- The standard enthalpy of H_2 at 1 atm and 298 K is zero.
- H_f° , Here subscript "f" stands for formations and superscript "°" indicates enthalpy at standard state.
- **Standard enthalpy change of reaction** is equal to difference between the sum of the standard

enthalpies of formation of products and the sum of the standard enthalpies of reactants i.e

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{product} - \sum \Delta H_f^\circ \text{reactants}$$

- **Standard enthalpy of formation (ΔH_f°)**: It is defined as the change in enthalpy that takes place when one mole of compound is formed from its elements which exist in their natural states.
- The standard state of any substance is taken its natural state at 298K or 25°C under one atmospheric pressure.
- **Standard enthalpy of combustion (ΔH_c°)**: The amount of heat produced when one mole of compound in its standard state, is completely burnt in excess of air or oxygen.
- Heat of reaction = $\Delta H^\circ = [\sum \Delta H_f^\circ \text{product}] - [\sum \Delta H_f^\circ \text{reactants}]$
- **Standard enthalpy of Neutralization (ΔH_n°)**: The amount of heat produced when one mole of hydrogen ions from acid and one mole of hydroxide ions from base react to form one mole of water.
- The heat of neutralization for strong acid and strong base reaction is $-57.4 \text{ kJ mol}^{-1}$.
- **Standard enthalpy of solution (ΔH_s°)**: The amount of heat evolved or absorbed when one mole of given substance is dissolved in an excess solvent so that further dilution results in no detectable change.
- **Enthalpy change of Hydration**: The change in enthalpy when an ion is transferred from the gas phase into aqueous solution.
- The Bond breaking of NaCl is endothermic processes.
- The energy requires to break one mole of NaCl is 411.15 kJ.
- The positive ions attract the negative end of polar solvent molecule, while the negative ion attracts its positive ions and the ions are said to be solvated.
- When water is used as solvent, it is called hydrated.
- **Lattice Energy**: The energy liberated when one mole of an ionic crystal is formed from its constituent ions in the gaseous state is known as lattice energy of that compound.

Measurement Of Enthalpy Change

- Enthalpy change can be measured by three ways:
 - Direct calorimetry
 - Indirect calorimetry
 - Van't hof equation
- By direct calorimetry we find enthalpy change for that reaction where there is side reaction.
- Direct calorimetry is used for:
 - Neutralization reaction
 - Combustion processes
- Heat of reaction = $q = n C \Delta T$
- In indirect calorimetry, we use Hess's law.

Hess's Law

- Hess's law states that the amount of energy evolved or absorbed in a chemical reaction is the same whether the reaction takes place in a single or several steps
- We can find heat of those reaction which cannot be find directly using Hess's law.
- According to Hess's Law: $\Delta H = \Delta H_1 + \Delta H_2$
- Applications of Hess's Law:
 - Heat of formation
 - Born Haber Cycle
- ΔH can be measured directly by using Hess' Law
- $\Delta H = \Delta E + P \Delta V$ (for gases)
- $\Delta H = \Delta E$ (for liquids and solids)

Born-Haber cycle

- The Born Haber cycle is based on principle, that sum of energy changes occurs in a closed cycle is zero.
- The Born Haber cycle involves law of conservation of energy.
- Born Haber cycle is the technique for applying Hess's law to the standard enthalpy changes, which occur when an ionic compound is formed.
- The energy liberated when one mole of ionic compound is formed from its constituent ions in the gaseous state is known as lattice energy.
- Lattice energy is in fact potential energy stored in the ionic crystal lattice.
- The heat of formation of NaCl is 410.03 kJ.
- $\Delta H_f^\circ = \Delta H_{\text{sub}}^\circ + \Delta H_{\text{ie}}^\circ + \Delta H_{\text{diss}}^\circ + \Delta H_{\text{lea}}^\circ + \Delta H_{\text{lat}}^\circ$
- For the NaCl Born-Haber Cycle, all the thermal values, except the lattice energy can be measured directly, and hence the cycle may be used, to calculate the Lattice energy of NaCl.

Chap No. 12 ELECTROCHEMISTRY

- The branch of chemistry that deals with the inter-conversion of the chemical changes and electricity is called electrochemistry.
- The flow of current in metals are due to flow of electrons.
- The passage of electricity through solutions of acids, bases and salts in accompanied by a chemical change.
- The substance which in solution or in molten state conducts electricity is called an electrolyte named by Arhenius.
- The substance which completely converted into ions in the solution or in molten state is called a strong electrolyte.
- The substance which is partially dissociated into its ions is called weak electrolyte.
- Electrolytic conduction or electrolysis is a phenomenon in which chemical changes takes place due to passage of the electric current at the electrodes.

Strong electrolyte:	Weak Electrolytes:
NaCl	NH ₄ OH
NaOH	H ₂ CO ₃
H ₂ SO ₄	CH ₃ COOH

- Oxidation-reduction reactions are responsible for the spoilage of food.
- Preservatives in food items act as reducing agents.
- Oxidation may also be linked with aging of humans.

- Vitamin C and vitamin K are natural reducing agents.
- The vitamin C in lemon juice can be used to prevent oxidation on the cut surface of an apple, to keep it from turning brown.
- Natural reducing agents can slow the pace of oxidation in the human body.

Oxidation-Reduction

Concept	Oxidation	Reduction
Classical	Addition of oxygen Removal of hydrogen	Removal of oxygen Addition of hydrogen
Electron transfer concept	Loss of electrons	Gain of electrons

- The substance which oxidizes other and itself get reduced during this process is called oxidizing agent.
- The oxidation number of oxidizing agent decreases.
- The substance which reduces other substance and itself gets oxidized during this process is called reducing agent.
- The oxidation number of reducing agent increases.

- The oxidation state is the apparent charge positive or negative which an atom would have in a molecular or ion.
- Valency is only a number while oxidation state indicates the positive or negative character of the atom.
- The oxidation number of free element is zero.
- The oxidation number of hydrogen in its compound is +1 but in metal hydrides it is -1 e.g. NaH and MgH₂.
- The oxidation number of oxygen in the compound is -2 but in peroxides it is -1 and in OF₂ is +2.
- The oxidation number of group I, II and group III are +1, +2 and +3 in compounds.
- The oxidation number of group VII are -1 in binary compounds.
- The algebraic sum of the oxidation numbers of all atoms in a molecule is zero.
- The algebraic sum of the oxidation numbers of all the atoms in an ion is equal to the charge on the ion.
- When an atom is oxidized, its oxidation number increases.
- When an atom is reduced, its oxidation number decreases.
- **Addition of Oxygen (Oxidation)**
 $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
 $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$
 $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$
 $\text{Na}_2\text{SO}_3 + \text{H}_2\text{O}_2 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$

Balancing Oxidation Reduction Equations

- There are two symmetric ways for balancing these equations:
 - Oxidation number method
 - Half reaction method
- Half reaction method is also called the ion electron method.
- No oxidation number is assigned in ion electron method.
- Ion Electron method applies to redox equations taking place in aqueous medium.

Steps of Balancing Redox Equations by Oxidation Number Method;

- Write down the skeleton of redox equation.
- Write the oxidation numbers over the symbol of the atom whose oxidation number changes during reaction.
- Identify the oxidizing and reducing agents, which undergo change in their oxidizing number.
- Indicate the change in oxidation number by an arrow which show the number of electron lost or gained.

- Multiply the formula of the oxidizing and reducing agents by a number such that the number of electrons lost and electrons gain becomes equal.
- Balance the rest of equation by simple inspection.

Steps of Balancing The Redox Equations By The Half Reaction Method;

- Split the equation to two half cells, one for oxidation and other for reduction.
- In neutral medium add H₂O and H⁺ ions can added to each side independently.
- In acidic medium, H₂O can be added to lower number of oxygen containing side and H⁺ ions can added to that side where the number of oxygen is high.
- In basic medium, H₂O can be added to side that contains higher number of oxygen and OH⁻ ions can added to that side where the number of oxygen is low.
- Balance the charge by adding electrons to either side.
- Multiply each half cell by such number, that the number of electron lost becomes equal to number of electrons gain.
- Add the two half cells reaction, resulting from the multiplications.
- Cancel anything appearing to both sides in the net equation.
- Check the final equation by counting the number of atoms and the net charge on either side.

Reaction of Oxidizing Agents

- K₂Cr₂O₇ and KMnO₄ are strong oxidizing agents in the presence of sulphuric acids.
- Potassium dichromate is reduced from +6 oxidation state to +3 oxidation state.
- Potassium dichromate oxidizes iodine to iodide.
- Potassium dichromate oxidizes ferrous (+2) salt to ferric (+3) salts.
- KMnO₄ in the presence of sulphuric acid oxidizes KI to I₂.
- KMnO₄ oxidizes oxalic acid in the presence of sulphuric acid to CO₂.

Reaction of Reducing agents

- H₂S and SO₂ are reducing agents in the presence of acids.
- H₂S reduces halogens to halogen acids.
- H₂S reduces ferric salts to ferrous salts.
- SO₂ react with KIO₃ and reduces it to I₂.
- SO₂ reduces KMnO₄ in acidic medium.

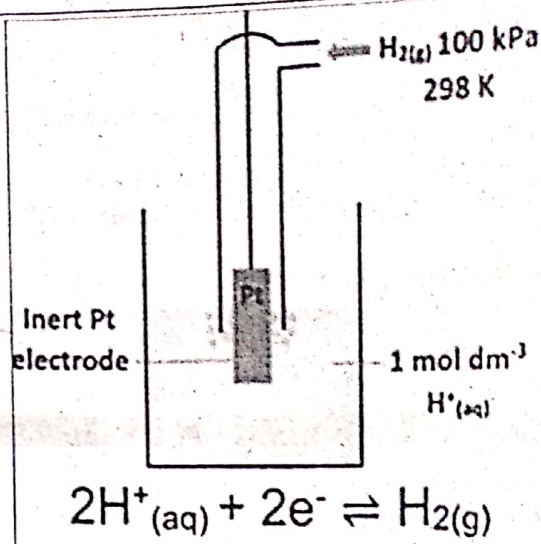
Electrodes

- Electrodes are metallic plates, wires or rods through which current enter and leave the electrolyte in a cell.
- The positive electrode is called anode.
- The negative electrode is called cathode.
- Anions move towards anode and get discharged by giving their electrons to the electrode.
- Cations move towards the cathode and gain the electrons and neutralize their charge.
- Oxidation occurs at anode.
- Reduction occurs at cathode.
- The number of electrons gained in reduction is equal to the number of electrons lost in oxidation.

Faraday's Law of Electrolysis

- Michal Faraday in 1813 gave a relation between the quantity of electricity passed and the amount of substances deposited at the electrode.
- First law: The amount of any substance (W) deposited or liberated at an electrode is directly proportional to the quantity of electricity or charge (Q) passed.
 - ✓ $W \propto Q$
 - ✓ $W \propto It$
 - ✓ $W \propto ZIt$
- Second Law: If the same amount of electricity is passed through different electrolytes, the amounts of different substances deposited are in the ratio of their chemical equivalent.
 - ✓ $W \propto \text{chemical equivalent (e)}$
 - ✓ $W \propto e$
 - ✓ $\frac{W_1}{W_2} = \frac{e_1}{e_2}$
 - w_1 = weight of the first element,
 - W_2 = weight of the second element
 - e_1 = chemical equivalent of first element
 - e_2 = chemical equivalent of second element.
- $Q \propto It$ and $Q \propto e$, adding these those gives us $Q \propto It = Ite/F$
- F is faradays constant which has a value of 96500c.

Electrode potential



- Potential difference set up between metal and its solution is called single electrode potential.
- The potential set up when an electrode is in contact with one molar solution of its own ions at 298K is known as standard electrode potential of the element.
- Standard electrode potential is represented by E° .
- Standard electrode potential of hydrogen has arbitrarily been chosen as zero.
- The standards electrode potentials of other elements can be found by comparing them with standard hydrogen electrode potential.

Standard Hydrogen Electrode, SHE.

- It consists of platinum, the electrode is suspended in 1M HCl solution at 25° C.
- Platinum is covered with layer of finely divided platinum electrolytically for the purpose to increase its surface area and increase its reaction.
- Pure hydrogen gas is bubbled over the platinum electrode at one atmospheric pressure.
- Reduction as well as oxidation so to be measured potential is the standard electrode potential of the other electrode by comparing it with the standard hydrogen electrode potential.
- Hydrogen electrode when coupled with the electrode which has positive E°_{Red} value, the electrode will act as cathode and SHE as anode
- If SHE is coupled with Zn electrode then reduction will take place at SHE, because the value of E°_{Red} is negative value as compared to SHE.
- E°_{Red} of Cu is value of +0.34V.

Measurement of Electrode potential

- The two solutions are interconnected by salt bridge.
- The potential difference is measured by voltmeter which gives the potential of the electrode as the potential is SHE is zero.

- An oxidation or reduction may take place at SHE depending upon the nature of the electrode which is coupled with it.
- Zinc has greater tendency to give off electrons than hydrogen.
- The oxidation potential of Zinc is 0.76 volts.
- The reduction potential of Zinc electrode is -0.76 volt.
- Standard reduction potential of copper is 0.34 volts.
- $E^0_{\text{cell}} = E^0_{\text{red}} + E^0_{\text{oxi}}$

Cell Representation

- A cell can be represented in one single line.
- The anode is represented at the left separated by a vertical line from its ionic solution.
- The cathode is at extreme right separated by a vertical line from its ionic solution.
- The two half reactions are separated by two parallel vertical lines which indicate the salt bridge.
- $\text{Zn}/\text{Zn}^{+2} (1\text{M}) // \text{Cu}^{+2} (1\text{M}) / \text{Cu}$
- A//C

Electrochemical Cells

- Types:
 - Electrolytic cell
 - Purification of metals
 - Charging of batteries
 - Nelson's cell
 - Voltaic or Galvanic Cell
 - Dry cells
 - Lead storage batteries
 - Daniel Cell
- In electrolytic cells, the electrical energy from an external source is used to bring about a chemical change.
- In Voltaic or Galvanic cell, the chemical energy is converted into electrical energy.
- Electrolytic cell: Electrical $\rightarrow$ chemical

Electrolytic cell

- Its device in which non-spontaneous reaction is carried out by passing electric current.
- When an electric current is passed through electrolytic solution, its ions move towards opposite charged electrodes.
- The anions liberate the electrons at anode and are said to be oxidized.
- The cations surround the cathode, consume those electrons and get deposited at the electrode.
- The number of electron lost is always equal to number of electrons gained.

Electrolysis of Aqueous NaCl

- The formula of caustic soda is NaOH.
- NaOH is manufactured on large scale by electrolysis of aqueous solutions of NaCl.
- The electrolysis is carried out in a cell called Nelson's cell and also by Downs cell.
- The graphite anode is suspended in solution.
- Cathode is made of a sheet of perforated steel.
- $2\text{NaCl} \rightarrow 2\text{Na} + 2\text{Cl}^-$
- At anode $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$
- At Cathode $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$
- Overall reaction $2\text{Cl}^- + 2\text{H}_2\text{O} \rightarrow \text{Cl}_2 + 2\text{Na}^+ + \text{H}_2 + 2\text{OH}^-$
- $2\text{Na} + 2\text{OH}^- \rightarrow 2\text{NaOH}$
- Cl_2 is released at anode.
- H_2 is released at cathode.
- NaOH is released at the bottom of the cell

Advantages of Electrolytic cell

- Charging of battery
- Manufacturing or extractions metals
- Purification of metals
- Plating of metals

Electroplating

- The metallic article to be electroplated is made as cathode.
- A sheet of pure metal to be deposited is made is anode.
- Salt of the metal to be deposited is taken as the electrolyte.
- When current is passed, the metal from anode is deposited on the cathode.

Voltaic Cell

- In the voltaic cell a spontaneous oxidation reduction reaction is carried out and electrical current is produced
- Voltaic cell contains two half cells.
- At one electrode electrons enters resulting in reduction reaction while the other they leave the solution and oxidation takes place.
- A typical example of voltaic cell is Daniel cell.

Daniel Cell

- This cell has a zinc electrode dipped into 1M ZnSO_4 solution and a Cu electrode immersed in Cu^{2+} ions.
- The two half cells are connected externally through a metallic wire.

- The two half cells are internally connected by a salt bridge.
- The salt bridge contains an aqueous KCl solution in gel.
- Zinc tends to lose electrons more readily than Cu.
- At Anode: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2e^-$
- At Cathode: $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$
- Net reaction: $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$
- $E_{\text{oxi}}^0 = +0.76 \text{ V}$
- $E_{\text{red}}^0 = +0.34 \text{ V}$
- $E_{\text{cell}}^0 = 1.10 \text{ V}$
- $\text{Zn}_{(s)} / \text{Zn}^{2+}_{(\text{aq})} (1\text{M}) // \text{Cu}^{2+}_{(\text{aq})} (1\text{M}) / \text{Cu}_{(s)}$

Batteries

- Primary battery: not reversible
- Secondary battery; reversible and rechargeable
- Solar battery; photoelectrical cells
- Fuel cells: super batter and high charge density
- Examples :

Primary → dry cell

Secondary → lead storage battery

Primary Batteries

- The container is made of Zinc which act as Anode.
- The container is lined with porous paper.
- A graphite rod in the center of the cell acts as cathode.
- Electrolyte is a moist mixture of:
 - NH_4Cl
 - MnO_2
 - ZnCl_2
 - Powdered carbon
- At Anode: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2e^-$
- At Cathode: $2\text{MnO}_2 + 2\text{NH}_4^+ \rightarrow \text{Mn}_2\text{O}_3 + 2\text{NH}_3 + \text{H}_2\text{O}$
- Net Reaction: $\text{Zn} + 2\text{MnO}_2 + 2\text{NH}_4^+ \rightarrow \text{Zn}^{2+} + \text{Mn}_2\text{O}_3 + 2\text{NH}_3 + \text{H}_2\text{O}$
- $\text{NH}_3 + \text{Zn}^{2+}$ forms complex ion.
- This is irreversible because Zn and NH_4^+ are consumed and cannot be reversed to their initial states.

Secondary Batteries

- It is combination of two or more voltaic cells of the same kind.
- The anode is made of Pb plates.
- The cathode is made of PbO_2 .
- The electrolytic solution is used as that of H_2SO_4 .
- At Anode: $\text{Pb} + \text{H}_2\text{SO}_4 \rightarrow \text{PbSO}_4 + 2\text{H}^+ + 2e^-$
- At Cathode: $\text{PbO}_2 + \text{H}_2\text{SO}_4 + 2\text{H}^+ + 2e^- \rightarrow \text{PbSO}_4 + 2\text{H}_2\text{O}$
- Net Reaction: $\text{Pb} + \text{PbO}_2 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$

- When the cell works, insoluble PbSO_4 is formed and gets deposit on each electrode, H_2SO_4 is consumed and water is formed.
- This battery is Reversible and if current external source is reversed, the above reaction will also reverse. The $2\text{PbSO}_4 + 2\text{H}_2\text{O}$ will reforms Pb, PbSO_4 and H_2SO_4 .

Fuel Cells

- An electrochemical device used for continuously converting chemicals into direct D.C current is called fuel cell.
- It consists of two electronic electrodes, separated by ionic electrolyte with the provision of continuous movement of fuel.
- The fuel can be:
 - Solid
 - Liquid
 - Gas
 - Solution
- Their operating time is unlimited.
- Electrodes are hollow tubes made of porous compressed carbon impregnated with platinum.
- The electrolyte is KOH.
- Hydrogen is oxidized at anode giving electrons to the outer circuit while the electrons are accepted at the cathode where reduction occurs and in this way current flows.
- $2\text{H}_2 \rightarrow 4\text{H}^+ + 4e^-$
- $\text{O}_2 + 4\text{H}^+ + 4e^- \rightarrow 2\text{H}_2\text{O}$
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
- The major drawback of fuel cell is that they are very costly.
- The gases must be of very high purity otherwise even a trace of impurity may poison the platinum which severely degrades its efficiency.
- The efficiency of fuel cell is 75%.

Corrosion

- The slow and continuous eating away of any metal by the action of metal is called corrosion.
- Pure iron is silvery while corroded are reddish brown.
- The impure or stained portion act as cathode.
- The pure iron act as anode.
- Anode: $2\text{Fe} \rightarrow 2\text{Fe}^{2+} + 4e^-$
- Cathode: $2\text{H}_2\text{O} + \text{O}_2 + 4e^- \rightarrow 4\text{OH}^-$
- Fe (II) is oxidized by oxygen to Fe(III), $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + e^-$
- $\text{Fe}^{3+} + 3\text{OH}^- \rightarrow \text{Fe}(\text{OH})_3$
- The rust mass is soft and porous in nature and therefore cannot prevent further atmospheric action.
- Once the corrosion starts it continuous until the whole iron piece is rusted.
- Corrosion cannot be completely eliminated or prevented.

Corrosion

- Coating the metal with zinc is called galvanizing.
- Coating the metal with tin is called tinning.
- Phosphate bath consists of orthophosphoric acid with zinc and manganese phosphate.
- Metal is generally coated with sacrificial metals.

Prevention of corrosion is done by:

- Coating
- Electroplating with nickel or chromium
- Dipping iron into phosphate bath
- Alloying the metal such as steel formation
- Cathodic protection

MIX FIRST YEAR

- The sum of mole fractions of solute and solvent is always equal to 1 or 1.0
- One mole is the amount of substance which contain as many element particles as there are in 0.012kg of C-12
- The solids in which the molecules or ions are arranged in a regular repetitive manner are called crystals
- The α bond between carbon and oxygen atoms in aldehyde and ketone due to overlap of sp^2-sp
- The ionization potential of hydrogen atom is 13.6 V
- The melting point and boiling point of ionic solids are High
- If radius of circle become half keeping other quantities constant, then percentage change in centripetal force is 100%
- The London dispersion forces are present in polar and Non polar molecule
- The frequency of electromagnetic do not change in Vacuum
- If electron moves from 1 to 2 orbit, the radius of orbit will increase 4 times
- The first law of thermodynamics has a statement which implies that Energy is conserved
- The bond in NaH is Ionic bond
- Liquids crystals are Isotropic
- Because of regular and well ordered arrangement crystalline solids are Anisotropic
- Crystalline solids are also called True solids
- Amorphous solids are also called Super cooled liquids
- In the periodic table, period represent The number of shells in an element
- In the periodic table, group represents Number of outermost shell electrons
- The wavelength of radio waves > microwaves > IR > VL > UV > X-rays > Gamma rays
- The weight of the molecules exerts a force on the wall of the container is cause of exerting pressure by Ideal gas
- The precipitation of AgCl will occur if ionic product is More than K_{sp}
- Number of hydrogen atom presents in one mole of water is 1.204×10^{24} atoms
- Charge on one electron 1.6022×10^{-19} C
- Number of electrons in one coulomb of charge is 6.25×10^{18}
- If K_c for certain reaction is large it indicates that Product concentration will be high
- $AlCl_3$ is Lewis acid
- Forces controlling the reaction are proportional to the product of active masses The law of mass action
- Hydrogen bond is possible in NH_3
- Most stable covalent hydride HF
- At constant temperature when volume of given mass of gas is doubled its density becomes Half
- In all reversible process the entropy of the system Increases
- 0.1000 Mole of NaCl is dissolved in 1.000dm³ distilled water at 298K, the concentration of resulting solution is 0.1000 M
- Mosely derives a direct relationship between the frequency of x-rays emitted by an element bombarded with high energy electrons, on what characteristic of the element does it depend Atomic number
- The intensity of x-rays depend upon nature of material of target
- The charge of electron was determined by R Milliken
- The e/m ratio of an electron was determined by J.J Thomson (1897)
- Metals are good conductors because It has free electrons
- The energy of electron in shell is given by $E_n = -1312/n^2$
- The number of electron in one coulomb of charge are 6.25×10^{18}
- The solubility of solute depends upon Pressure, Temperature, nature of solute And solvent
- Heat capacity of substance at constant volume is directly related to the Internal energy
- The number of orbitals in "M" shell of an orbit is 9
- H_2 most closely represent Ideal gas

- > At constant temperature, the pressure of the gas is doubled its volume becomes One half
- > Angular acceleration in the body is produced by Torque
- > The span of broad depends upon jumper's Angle of projection
- > Evaporation occurs at All temperature
- > The rate of reaction is defined as $-\frac{dC}{dt}$
- > According to bronsted and lowery concept SO_4^{2-} cannot function as acid
- > When electron jump from one shell to another it emits energy, it was said by Bohr
- > equal volume of all gases at same temperature and pressure contain same number of particles Avogadro's law
- > NI_3 contain Six bonded electrons
- > An orbital may never be occupied by 3 electrons
- > Glass in an example of amorphous solid which can be characterized as Very viscous fluid
- > Four balloons filled with different gases, hydrogen filled balloon flew High
- > During redox reaction an oxidizing agent Gain electrons
- > The penetrating power of x-rays depends on Operating voltage
- > $1s\ 2s\ 2p\ 3s\ 3p\ 4s\ 3d\ 4p\ 5s\ 4d\ 5p\ldots$ electronic configuration
- > The paramagnetic nature of substance depends on number of Unpaired electrons
- > The value of K_c is different at Different temperature
- > Standard solution are prepared in Volumetric flask
- > Nitrogen has three unpaired electrons according to Hund's rule
- > Standard hydrogen electrode may act as both cathode and anode
- > Stoichiometric calculation based on chemical equation provides us estimation about Theoretical yield
- > The phenomenon of gas cooling by sudden expansion is called Joule Thomson Effect
- > Both hydrogen and helium is same number of Shells
- > CO_2 is iso-structural with C_2H_2
- > $CaCO_3, CaC, KCN$ are Inorganic
- > $(NH_2)CO$ is Organic
- > Molecules of oxygen is diatomic and behaves as paramagnetic
- > $HClO_4$ is strongest Acid from $HClO_1, HClO_2, HClO_3$
- > $TiCl_4$ is use as catalyst for the manufacture of ammonia
- > The shapes or appearance in which crystal grows is called Crystal habit
- > SO_2 is responsible for the formation of Acid rain
- > A catalyst is more effective when it is in the finally divided state because It increase in surface area
- > Electronic configuration of an element is $ns^2 np^2$ it belongs to group 4th of periodic table
- > $CaCl_2$ anhydrous is use as Drying agent
- > Water boils at high temperature than HF because Hydrogen bonding per molecule in H_2O is greater than HF
- > An atom has net charge of -1 it has 18 electrons and 20 neutrons. its mass number is 37
- > The ionization energy of hydrogen atom is 13.6 eV. the ionization potential require will be 8.5×10^{-10} volt
- > Elements having same chemical properties belongs to same Group (3,11)
- > The oxidation number of Cl in $Ca(ClO_3)_2$ is +5
- > Trade name of tetrafluoro ethylene polymer is Teflon
- > Sum of number of neutrons and protons are called Mass number
- > Water at 40°C is Heaviest
- > The most electronegative element is found in period 2
- > The bond present in solid mercury is Metallic bond
- > Substance dissolved in water react better because water Dissolves them in ions
- > 4.0 dm³ of O_2 at a pressure 800 atm and 1 dm³ of N_2 at pressure of 100 atm are put in 2 dm container, the total pressure is 900 atm
- > The amount of heat required the temperature of 1 calorie of substance through 1 K is called Heat capacity
- > The group of animals which can run fast is Digitgrade
- > NaCl does not conduct Electric current
- > The bonds present in NH_4Cl are Ionic, Covalent and co-ordinate covalent bond
- > In $PV=nRT$ here n is number of moles
- > London dispersion forces are present in Solid, liquid and gases
- > Stability of ionic compound is due to Lattice energy
- > The excited state of an atom which can persist for unusual longer time is Metastable state
- > A zero order reaction is one whose rate is independent of Reactant concentration
- > If the distance between two charged particle is halved. The coulomb's force between them becomes Four times
- > The neutralization of strong acid by a strong base liberates an amount of energy per mole of H^+ ion that is Always the same
- > Spreading of smell in room is due to diffusion
- > A well stoppered thermos flask containing some ice cubes is an example of Isolated system
- > NH_3 and HCl are present at both side of pipe and diffuse to react and form NH_4Cl , the NH_4Cl will form near the HCl end
- > Vapor pressure of mercury is less than Rectified spirit, kerosene oil and Water

- A concentrated solution has got High solute potential
- Molecular formula of an acid $\text{C}_2\text{H}_4\text{O}_2$ is $\text{C}_2\text{H}_4\text{O}_2$
- The best known fuel cell is the hydrogen/ oxygen fuel cell. This is known as Bacon cell
- CO_2 is non-polar but contained Polar bonds
- The emf from galvanic cell can be calculated from The E0 value of the half cell
- A liquid is in equilibrium with its vapors at its boiling point. On the average the molecules in the two phase have equal Total energy
- Reason for alkali metals to be soft is that, they have Not closed packed structure
- If the pressure and temperature of 2 litres of CO_2 are doubled, the volume will become 2 litres
- Atoms present in one mole of $\text{Ca}(\text{OH})_2$ are $5 \times 6.023 \times 10^{23}$ atoms
- Aluminum is resistant to Corrosion
- CH_4 & SiH_4 have same Structure
- A mixture of 50g H_2 and 50 He has a total pressure of 1.5atm. partial pressure of H_2 gas is 1.0 atm
- Calculate the volume occupied by 2.8g of nitrogen gas at STP is 22.4dm³
- A piece of wood and iron seen to lose the same weight when completely submerged in liquid. The two pieces must have the same Volume
- A solution of 2.0g NaOH dissolved in 1000 g of water has concentration 0.05M
- Bohr's theory explains He^+ , Li^{++} , Be^{+++}
- The oxidation number of hydrogen in metal hydrides -1
- In discharge tube Neon gas will produce Pink colour
- The value of principle quantum number $l=1$, the value of magnetic quantum number(m) are 1,0,+1
- The study of heat changes accompanying a chemical reaction is known as Thermo-chemistry
- On complete oxidation, one mole of an organic compound gave four moles of water, which is Propane
- Water is not used as thermometric liquid because it does not Expand linearly
- Number of moles of NaCl in 75.0g of table salt 1.28
- Oxygen atom has two unpaired electrons it is therefore Paramagnetic
- The sample of compound contain 0.100g of hydrogen and 4.20g of nitrogen, the compound is NH_3
- Hybrid orbitals used by carbon atoms in C_2H_4 is Sp^2
- Hybrid orbitals used by carbon atoms in C_2H_2 is Sp
- Hybrid orbitals used by carbon atoms in C_2H_6 is Sp^3
- Esters are represented by general formula RCOOR
- Ag_2S is a Not common occurring sulphur compound
- Theoretical yield is always less than actual yield because of Reversibility, Side reaction, Mechanical loss, Human error

BANK OF MCQS

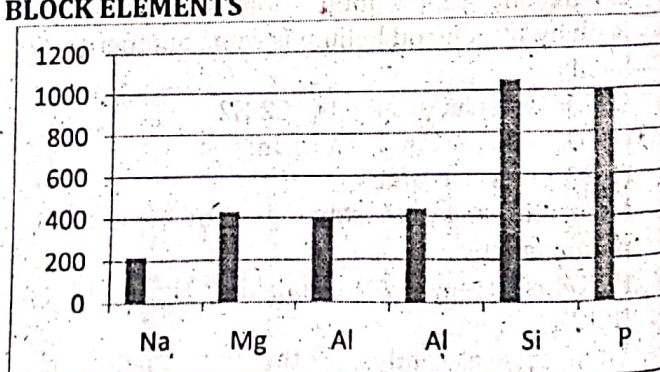
Chap No. 13 S AND P BLOCK ELEMENTS

- +Group-I → alkali metals
- Group-II → alkaline earth metals
- S → only metals
- P → metals + non-metals

3rd Period (Na to Ar)

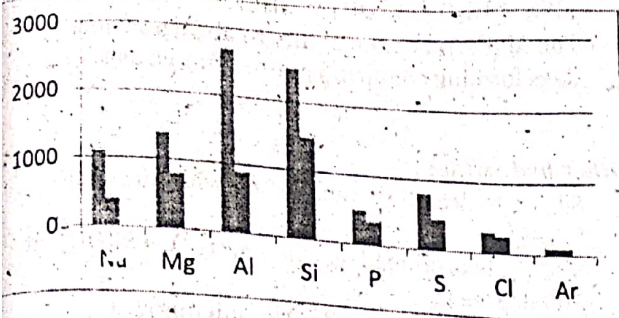
Physical and atomic properties

- Na - Mg - Al - Si - P - S - Cl - Ar
- Metallic radii for sodium, magnesium and aluminium.
- Covalent radii for silicon, phosphorus, sulphur and chlorine
- Van der wall radii for Argon.
- Ionization energy increase from left to right, exception → Al and S.



- Electronegativity increases from left to right, exception → Ar
- Sodium, magnesium and aluminium are best conductors.
- Silicon is semiconductor.
- Phosphorus, sulphur, chlorine and argon are non conductors.

Melting point and boiling point values increase up to Al and then decreases.



Metal	Water	Oxygen	Chlorine
Na	NaOH	Na ₂ O Na ₂ O ₂	NaCl
Mg	Mg(OH) ₂ MgO	MgO	MgCl ₂
Al	Al ₂ O ₃	Al ₂ O ₃	AlCl ₃
Si	SiO ₂	SiO ₂	SiCl ₄
P		P ₄ O ₆ P ₄ O ₁₀	PCl ₃ PCl ₅
S		SO ₂	S ₂ Cl ₂
Cl	HCl + HOCl	Cl ₂ O, Cl ₂ O ₇	

Reaction of 3rd period elements with water, oxygen and chlorine

- Magnesium and aluminium form layers when reacting with water.
- Sodium undergoes exothermically reaction with cold water.
- Magnesium reacts slowly with cold water and burn in steam producing Mg(OH)₂ and MgO.
- Magnesium burnt in steam with its typical white flame.
- Chlorine dissolves in water and produces green solution.
- Reaction with

- Sodium burns in oxygen with yellow flame.
- Sodium forms normal oxide and also per oxides.
- MgO and Al₂O₃ are of white colour.
- Aluminium burns in oxygen when it is powdered.
- Silicon will burn in oxygen if heated strongly well and SiO₂ is produced.
- White phosphorus catch fire spontaneously in air with white flame and forms phosphorus (III) oxide and phosphorus (IV) oxide.
- Sulphur burns in oxygen with pale blue flame.
- SO₂ is colourless.
- PCl₃ → colourless fuming liquid
- PCl₅ → straw colour solid
- S₂Cl₂ → orange, foul smelling liquid

Formula of oxide	NaCl	MgCl	Al ₂ Cl ₆	SiCl ₄	PCl ₃	S ₂ Cl ₂
State	S	S	S	L	L	L
Conductivity	G	G	v.poor	NILL	Nill	Nill
Strucuture	Giant	Giant	Simple molecular	Simple molecular	Simple molecular	Simple molecular
Effect on adding water	Solid dissolves readily			Chlorides react and produces fumes of HCl		

Formula of oxide	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀ P ₄ O ₆	SO ₃ SO ₂	Cl ₂ O ₇ Cl ₂ O
State	S	S	S	S	S	L G	L G
Conductivity	G	G	G	v.poor	Nill	Nill	Nill
Strucuture	Giant	Giant	Giant	Giant	Simple molecular	Simple molecular	Simple molecular
Nature	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic	Acidic
	Metal oxides						

Formula of oxide	Na ₂ OH	Mg(OH) ₂ Ca(OH) ₂	Al ₂ (OH) ₃	Si(OH) ₄	H ₃ PO ₄	H ₂ SO ₄	HClO ₄
Nature	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic	Acidic

Acid, Base Behavior of oxides;

Al_2O_3 does not react with but react with dilute acids and dilute alkali.

- $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$
- $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^- \rightarrow$ aluminate ion
- SiO_2 does not react with water, but it does react with concentrated alkalis forming silicates SiO_3^{2-} .
- NO_2 react with water forming HNO_2 and HNO_3 .
- The oxides of P, S and Cl except ClO_2 react readily to form strongly acidic solution
- $2HClO_4 \rightarrow$ Perchloric acid

Reaction of oxides with water, acid and bases;

- Metal oxides $\rightarrow$ Basic $\rightarrow$ Ionic
- Non-Metal oxides $\rightarrow$ Acidic $\rightarrow$ Covalent
- Normal oxides of most metal combine with acids to form salts. these are called basic oxides.
- Basic oxides alts dissolve in water to give soluble hydroxides.
- Acidic oxides are oxides of non-metals such as CO_2 and SO_2 .
- Acidic oxides react with bases to form salts and combine with water to form acids.
- BeO and Al_2O_3 are amphoteric.

Sodium and magnesium hydroxides;

- $NaOH \rightarrow$ soap, peteroleum and rubber industry
- These are white solids having soapy touch.
- Sodium hydroxides is only slightly soluble in water,
- Sodium hydroxides is the most soluble substances in water evolving a considerable amount of heat due to the
- formation of a number of hydrates such as $NaOH \cdot 2H_2O$
- Magnesium hydroxide is obtained as white ppt when caustic potash us added to a soluble magnesium salt.
 $MgCl_2 + 2KOH \rightarrow Mg(OH)_2 + 2KCl$
- Solubility of $Mg(OH)_2$ is enhanced tremendously by the addition of NH_4Cl and NH_4OH is formed.
- $2NH_4Cl \rightarrow 2NH_4^+ + 2Cl^-$
- $Mg(OH)_2 \rightarrow 2OH^- + Mg^{2+}$
- $2NH_4^+ + 2OH^- \rightarrow 2NH_4OH$

Aluminium hydroxide

- When an alkali is added to aquaseous solution of aluminium salts, aluminium hydroxides get precipitated.
- $Al(SO_4)_3 + 6NH_4OH \rightarrow 2Al(OH)_3 + 3[(NH_4)_2SO_4]$
- The hydroxides is soluble in acids and caustic alkalis forming aluminates in the later.
- $2Al(OH)_3 + 2NaOH \rightarrow 2Na[Al(OH)_4]$

- The $Al(OH)_3$ can also be obtained by hydrolysis of $AlCl_3$ in excess water.
- $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$
- The $Al(OH)_3$ has the ability to absorb various dyes forming colouring matter known as lakes.

Other hydroxides

- Silicon hydroxide is a molecule with formula $Si(OH)_4$.
- $Si(OH)_4$ is produced as; $SiO_2 + 2H_2O \rightarrow Si(OH)_4$ at 800 degree C.
- $Si(OH)_4$ is unstable and form polymerizes.

Group-I A

- Li-Na-K-Rb-Cs-Fr
- Group first members are called alkali metals since they form oxides and hydroxides which combine with water to produce alkaline solution.
- Li-Na and K are safe to save in school lab and rest are violently reactive.
- They are softer than other metals and can cut with knife.
- These metals are lighter than other elements and having low melting point, boiling point and density.

Atomic and physical properties

- Down the group;
 - Atomic radius $\rightarrow$ Increases
 - Density $\rightarrow$ Decreases
 - Ionization energy $\rightarrow$ Decreases
 - Electronegativity $\rightarrow$ Decreases
 - M.P and B.P $\rightarrow$ Decreases
- Potassium is lighter than sodium.

Trend in reactivity with water

- Excluding Lithium, which reacts slower than al the other elements of group-I.
- The reactivity of group-I follow the values of electrode potential.

Reaction with oxygen

- Li, Na and K are stored in oil.
- Cs and Rb are normally stored in a sealed glass tube to prevent air contact.

Reaction with air or oxygen

- Alkali metals react with air or oxygen to form various oxides such as
- Li_2O and Li_3N
- Na_2O and Na_2O_2
- K_2O_2 and KO_2

- Rb and Cs form superoxide

Oxides;

- Li → normal oxide
- Na → normal and peroxide
- K → peroxide and superoxide
- Rb → superoxide
- Cs → superoxide

Reaction of oxides with water and dilute acids;

- Normal oxide; $X_2O + H_2O \rightarrow 2XOH$
- Peroxide; $X_2O_2 + 2H_2O \rightarrow 2XOH + H_2O_2$
- Superoxide; $2XO_2 + 2H_2O \rightarrow 2XOH + H_2O_2 + O_2$

Reaction with dilute acids

- Normal oxide; $X_2O + 2HCl \rightarrow 2XCl + H_2O$
- Peroxide; $X_2O_2 + 2HCl \rightarrow 2XCl + H_2O_2$
- Superoxide; $2XO_2 + 2HCl \rightarrow 2XCl + H_2O_2 + O_2$

Reaction with chlorine

- Sodium burns with intense orange flame in chlorine in exactly the same way as it does in pure oxygen,
 $2X + Cl_2 \rightarrow 2XCl$
 $2Na + Cl_2 \rightarrow 2NaCl$
- Compounds of Group-I A elements are more stable to heat than the corresponding compounds of Group-II elements with the exception of lithium compounds.

Effect of heat on nitrates;

- Colour of nitrogen dioxide is brown fumes.
- Lithium nitrate produces lithium oxide, nitrogen dioxide and oxygen.
 $4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$
- Nitrates of the other alkali metals decompose to corresponding nitrites.
 $2XNO_3 \rightarrow 2XNO_2 + O_2$

Effect of heat on Carbonates;

- Lithium carbonate decomposes on heating to give lithium oxide and carbon dioxide.
 $Li_2CO_3 \rightarrow Li_2O + CO_2$
- The rest of group-I carbonates do not decompose even at higher temperature.

Effect of heat on Hydrogen Carbonates;

- Carbonates of alkali metals are stable enough to be isolated as solids.
- Hydrogen carbonates decompose on heating forming carbonates.

- Thermal stability of hydrogen carbonates of group I and Group II increases down the group. The reason is increasing size and decreasing charge density of the metal ions.
- The polarizing power of a cation increases with increasing charge on the ion and decreasing the radius of the ion.
- Cation of greater polarizing power distorts the HCO_3 ion more and facilitates its decomposition than a cation of larger size and lesser polarizing power.
- Bicarbonates of group-I are more stable than those of group II and stability decreases down the group.

Flame Tests;

- Li → Red
- Na → Yellow
- K → Lilac
- Rb → Red
- Cs → Blue/violet
- Polarizing power is directly proportional to decomposition.
- Polarizing power is directly proportional to charge and inversely to radius.

Group-II A

- Alkaline earth metals do not exist free in nature.
- Magnesium and calcium are very abundant in the rocks of earth's crust.

Magnesium Sources;

- Sea water
- Underground brines
- Mineral dolomite
- Magnesite ($MgCO_3$)

Calcium Sources;

- Sea shell ($CaCO_3$)
- Gypsum ($CaSO_4 \cdot 2H_2O$)

Atomic and physical properties;

- All alkaline earth metal except Be are white in colour.
- Alkaline earth metals are quite reactive and tarnish in air.
- The value of their densities, melting point and boiling point are higher than those of alkali metals.
- Down the group;
 - Atomic radius → Increases
 - Ionization energy → Decreases (exc; $Ra > Ba$)

- Electronegativity → Decreases (Ca=Mg and Ba=Ra)
- Melting point and Boiling point → no regular term but greater than group first
- Reactivity with water → Increases
- Be does not react with water or steam at red heat.

Reaction with oxygen and Nitrogen;

	Simple oxide	Per oxide
Be	→	-
Mg	→	-
Ca	→	-
Sr	→	→
Ba	→	→
Ra	→	-

- The nitrides of alkaline earth metals are ionic in nature except that of Ba which is covalent and unpredictable.
- The reaction of alkaline earth metals with air rather than oxygen is complicated by the fact that they all react with nitrogen to produce nitrides.
- $\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$
- $\text{Be} + \text{N}_2 \rightarrow \text{Be}_3\text{N}_2$
- If alkaline earth metals react with air, they form metal nitrides and metal oxides.

Trends in solubility of hydroxides, sulphates and carbonates

- Solubility of hydroxides increases in water from top to bottom.
- Solubility of sulphates decreases down the group.
- Stability of carbonates increases down the group.
- All carbonates of alkaline earth metals are insoluble in neutral medium while all dissolve in solids and decompose at red heat.
- CaSO_4 is sufficiently soluble in water.
- Strontium and barium sulphates are almost insoluble.
- Both carbonates and nitrates become more thermally stable as we go down the group of alkaline earth metals.
- The one at lower position have to be heated more strongly than those at the top before they decompose.

Group-IV A

- C, Si, Ge, Sn and Pb.
- M.P and B.P decreases down the group.
- Melting point decreases because weaker bonds decrease with increase in atomic size.
- Tin and Lead do not use all the four electrons for metallic bond.
- C and Si are non-metals.
- Ge is metalloid.

- Sn and Pb is metallic character.
- Carbon and silicon show +4 oxidation state in carbonates and silicates.
- Ge, Sn and Pb can show +2 and +4 oxidation states.
- Oxidation state is defined as the apparent charge positive or negative on an atom of an element in a molecular ion.
- Down the group, there is tendency for the sp^2 pair not to be used in bonding. This is called inert pair effect which dominates in lead.
- Fajan's rule; Sn^{+4} is smaller than Sn^{+2} so the compounds of Sn^{+4} are covalent, while those of Sn^{+2} are ionic.
- All these elements give tetrachlorides (MCl_4) which are covalent and tetrahedral due to sp^3 hybrid orbitals.
- The stability decreases from CCl_4 to PbCl_4 .
- PbCl_4 decreases to give PbCl_2 and Cl_2 gas.
- At the top of the group, most stable oxidation state is +4 as shown by carbon and silicon in CCl_4 and SiCl_4 , they have no tendency to form dichlorides.

Reaction with water

- CCl_4 does not react with water due to bulky nature of chlorine atoms around small carbon atom.
- SiCl_4 and PbCl_4 react violently with water to reduce their respective oxides and fumes of HCl.
- $\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$
- $\text{SiO}_2 \rightarrow$ White
- $\text{PbO}_2 \rightarrow$ Brown
- $\text{PbCl}_4 \rightarrow$ covalent
- $\text{PbCl}_2 \rightarrow$ ionic
- PbCl_2 is sparingly soluble in cold water but more soluble in hot water.

Oxides

- The elements of group-IV form two types of oxides i.e. monoxide and dioxide.
- Monoxide include;
 - C O
 - Sn O
 - Pb O
- Dioxide include;
 - C O₂
 - Sn O₂
 - Pb O₂
- Non-metal oxidizes covalent in nature, such as oxidize of carbon and silicon.
- Metal oxidize are ionic in nature such as oxidize of tin and lead.
- $\text{CO}_2 \rightarrow$ Gas
- $\text{Si O}_2 \rightarrow$ Solid

- The SiO_2 is a giant covalent structure in which each silicon atom is bonded to four oxygen atoms through single covalent bonds whereas each oxygen atom is bonded to two silicon atoms.
- The geometry of the SiO_2 is tetrahedral (diamond like).

Acid Base Behavior of Group IV oxidizes

The acidity of group-IV oxides decreases as we go down the group.

- $\text{C O}_2 \rightarrow$ acidic
- $\text{Si O}_2 \rightarrow$ acidic
- $\text{Ge O}_2 \rightarrow$ amphoteric
- $\text{Sn O}_2 \rightarrow$ amphoteric
- $\text{Pb O}_2 \rightarrow$ amphoteric
- $\text{C O} \rightarrow$ neutral
- $\text{Sn O} \rightarrow$ amphoteric
- $\text{Pb O} \rightarrow$ amphoteric

Group VII A

- F-Cl-Br-I
- Also called halogens due to salt forming capacity.
- All are non-metals
- Exists as diatomic covalent molecule
- Poisonous in nature
- Down the group;
 - Radius $\rightarrow$ Increases ($\text{F} < \text{Cl} < \text{Br} < \text{I}$)
 - E.N $\rightarrow$ Decreases ($\text{F} > \text{Cl} > \text{Br} > \text{I}$)
 - E.A $\rightarrow$ Decreases ($\text{Cl} > \text{Br} > \text{F} > \text{I}$)
 - M.P and B.P $\rightarrow$ Increases ($\text{F} > \text{Cl} > \text{Br} > \text{I}$)

- Bond enthalpy; ($\text{Cl} > \text{Br} > \text{F} > \text{I}$)
- Bond enthalpy for hydrogen halides; ($\text{HF} > \text{HCl} > \text{HBr} > \text{HI}$)
- Oxidizing agent; $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$
- Reducing agent; $\text{I} > \text{Br} > \text{Cl} > \text{F}$
- HF is weaker acid than HCl, HBr and HI.
- Bond enthalpy is the amount of heat needed to break one mole of covalent bonds to form individual atoms.
- Bond enthalpy is the energy required to break a bond.
- H-I is easily decomposed.
- H-Br may or may not decomposed.
- H-F and H-Cl are so stable that they do not decompose at any temperature.
- When halogen combines with metal or non-metal, they normally act as oxidizing agent.
- F and Cl are so such powerful oxidizing agents that they can oxidize coloured dyes to colourless substances acting as oxidizing agent for the bleaching.
- HBr and HI dissolves in water in same way as HCl. By contrast although HF dissolves freely in water yet it is weak acid.
- Larger the size of halide ion, greater is its reducing agent.
- Br reduces sulphur in sulphuric acid from +6 oxidation state to +4.
- I reduces sulphur in sulphuric acid from +6 to -2 oxidation state.
- Poor nutrition enhances the toxicity of fluorides.

Chap No. 14 D and F BLOCK ELEMENTS

- Electronic configuration for D-shell; $(n-1)d^{1-10} ns^{0,1,2,3}$
- Binding energy increases up to VIB and then decreases.
- Oxidation states; +3 is common at beginning and +2 at the end.

Catalytic properties;

- Fe $\rightarrow$ Haber process $\rightarrow$ Ammonia synthesis
- $\text{V}_2\text{O}_5 \rightarrow$ Contact process $\rightarrow$ H_2SO_4 synthesis
- $\text{TiCl}_4 \rightarrow$ polymerization of ethene to polythene
- Ni, Pt and Pd $\rightarrow$ hydrogenation of unsaturated hydrocarbons.
- Cu $\rightarrow$ oxidation of ethanol to acetaldehyde.

Magnetic behavior;

- Weakly attracted $\rightarrow$ paramagnetic
- Weakly repelled $\rightarrow$ diamagnetic
- Paramagnetic $\rightarrow$ one or more unpaired electron
- Diamagnetic $\rightarrow$ paired electrons
- Ferromagnetic $\rightarrow$ five unpaired electrons like Fe^{+3} and Mn^{+2}

Alloy Formation;

- Gold $\rightarrow$ Cu = 20-25 %, Au = 70-75 % $\rightarrow$ 18 carat
- Brass $\rightarrow$ Cu = 60-80 %, Zn = 20-40 %
- Bronze $\rightarrow$ Cu = 75-90 %, Sn = 10-25 %
- Steel $\rightarrow$ Fe = 90-95 %, C = 0.1-2 %

Complex Ion

- A pale blue precipitate of Cu (II) hydroxide forms when ammonia is added to a solution of Cu (II) ions.
- If we add more ammonia to four ammonia molecules and two water molecules surrounds Cu^{+2} ion and deep blue solution of formula $[\text{Cu}(\text{H}_2\text{O}_2(\text{NH}_3)_4)]^{+2}$ is formed.

Nomenclature of coordination complex

- Cation is named first and anion later.
- Negative ligands ends with 'o'.
- Positive ligands end with 'ium'.
- Ligand of complex are named in order of negative $\rightarrow$ neutral $\rightarrow$ positive.
- Name of metal is followed by 'ate'.

- $[\text{Cr}(\text{NH}_3)_6](\text{NO}_3)_3 \rightarrow$ Hexaamminechromium (III) nitrate
- $\text{K}_2[\text{PtCl}_6] \rightarrow$ Potassium hexachloroplatinate (IV)
- $[\text{Co}(\text{NH}_3)_3(\text{NH}_2)_3] \rightarrow$ TrinitrotriamecobaIt (III)
- $[\text{Co}(\text{NH}_3)_4(\text{Cl}_2)]\text{Cl} \rightarrow$ Dichlorotetraamminecobalt (III) chloride
- $\text{Na}_3[\text{Co}(\text{NO}_2)_6] \rightarrow$ sodium hexachlorocobaltate (III)
- $\text{Na}_3[\text{Fe}(\text{CN})_6] \rightarrow$ sodium hexacyanoferrate (III)
- $\text{K}_3[\text{Fe}(\text{CN})_6] \rightarrow$ potassium hexacyanoferrate (III)
- $\text{Na}_2[\text{Fe}(\text{N})(\text{CN})_5] \rightarrow$ Sodium pentacyanonitrosylferrate (III)
- $[\text{Co}(\text{en})_2(\text{Cl})_2] \rightarrow$ Dichloro-Bi-ethylenediamine cobalt (II)

Shapes of complex ions

- 6- Coordinated complex ions has octahedral shape.
- 4- coordinated complex ions have tetrahedral and square planar complex.
- 5- coordinated complex ions have trigonal bipyramidal and square pyramidal shapes.
- $[\text{CuCl}_4]^{2-}$ and $[\text{CoCl}_4]^{2-}$ have tetrahedral ion geometry
- Cisplatin $\{\text{Pt}(\text{NH}_3)_2\text{Cl}_2\}$ has square planar structure

Colours of Complexes

- $\text{Sc}^{3+} \rightarrow$ Colourless
- $\text{Ti}^{3+} \rightarrow$ Purple
- $\text{Ti}^{4+} \rightarrow$ Colourless
- $\text{Cr}^{3+} \rightarrow$ Blue

- $\text{Mn}^{2+} \rightarrow$ Green
 - $\text{Fe}^{3+} \rightarrow$ Yellow
 - $\text{Co}^{2+} \rightarrow$ Blue
 - $\text{Ni}^{2+} \rightarrow$ Green
 - $\text{Cu}^{2+} \rightarrow$ Blue
 - $\text{Zn}^{2+} \rightarrow$ Colourless
- $\rightarrow 33-43-23-22-22 \rightarrow \text{p-bgy-bgb}$

Vanadium

- Vanadium was discovered by mistaken by Andres Manuel del Rio in 1801.
- Vanadium was rediscovered by Swedish chemist Nils Gabriel Sefstrom.
- The word Vanadis means goddess of beauty and love in Scandinavian mythology.

Oxidation states of vanadium(23)

- $\text{V}^{+2} \rightarrow$ Violet
- $\text{V}^{+3} \rightarrow$ Green
- $\text{V}^{+4} \rightarrow$ Blue
- $\text{V}^{+5} \rightarrow$ Colorless

As catalyst as contact process

- Platinum was used as catalyst for conversion of SO_2 to SO_3 but as it is susceptible to poisoning by arsenic impurities
- Vanadium oxide V_2O_5 is used as catalyst for conversion of SO_2 to SO_3 .
- V_2O_5 is also used as catalyst in oxidation of alcohol and hydrogenation of olefins or alkenes.
- Sulfuric acid is manufactured by contact process.

Chromium

- Atomic number 24
- Corrosion resistant
- Discovered by French chemist Louis Nicolas Vauquelin in 1797.
- Chromium forms a large number of coloured compounds.
- 21st in nature abundance among the elements in earth crust.
- Atomic weight 51.996
- Melting point 1907 degree C or 3465 $^{\circ}\text{F}$.
- Boiling point 2672 degree C or 4842 $^{\circ}\text{F}$.
- Specific gravity 7.2.

Chromium minerals

- Chromite or chrome iron stone ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$).
- Chrome ochre (Cr_2O_3)

- Crocite (PbCr_2O_3)

Oxidation states

Oxides	CrO	Cr ₂ O ₃	CrO ₃
Oxidation state	+2	+3	+6
Nature	Basic	Amphoteric	Acidic
	Ionic	Ionize to some extent	Covalent
	Chromous salt	Chromic compound	
	Oxidation	Stable	Reduction

The chromate - Dichromate equilibrium

- $\text{K}_2\text{Cr}_2\text{O}_4$ or solid potassium chromate, when dissolved in water, it forms a yellow solution.
- $\text{K}_2\text{Cr}_2\text{O}_7$ or solid potassium dichromate, when dissolved in water, it forms an orange solution.
- The colours come from the negative ions; CrO_4^{2-} and CrO_7^{2-} .
- $\text{CrO}_4^{2-} + 2\text{H}^+$ are in equilibrium with $\text{CrO}_7^{2-} + \text{H}_2\text{O}$
- Addition of acid to the reactant shifts the equilibrium towards right and yield more orange colour.
- The addition of a base promotes the conversion of dichromate to chromate.

Reduction of chromate (VI) with zinc and an acid;

- Potassium dichromate (VI) can be reduced to chromium (III) and chromium (II) ions by using Zinc either dilute sulphuric acid or hydrochloric acid.

Potassium Dichromate as oxidizing agent in organic chemistry

- Potassium dichromate (VI) solution acidified with dilute sulphuric acid commonly used as an oxidizing agent in organic chemistry.
- Potassium dichromate (VI) oxidizes primary alcohol to formaldehyde.
- Potassium dichromate (VI) formaldehyde to formic acid.
- Potassium dichromate (VI) oxidizes secondary alcohol to ketones.
- Potassium dichromate (VI) does not oxidizes tertiary alcohol.

Potassium Dichromate as oxidizing agent in titration

- In redox reaction a standard solution of potassium dichromate $\text{K}_2\text{Cr}_2\text{O}_7$ is used to determine the unknown concentration of a solution of Fe^{2+} .
- Dichromate ion reduces to chromium (III)
 $\rightarrow \text{CrO}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$
- Fe (II) is oxidized to Fe(III).
 $\rightarrow 6\text{Fe}^{2+} \rightarrow 6\text{Fe}^{3+} + 6\text{e}^-$
- $\text{CrO}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{Fe}^{3+}$
- $\text{CrO}_7^{2-} \rightarrow$ orange
- $\text{Cr}^{3+} \rightarrow$ green
- The 1:6 mole ratio with respect to amount of CrO_7^{2-} and Fe^{2+} is consumed.

Manganese

- Hite, silvery metallic element
- Used in making alloys
- First isolated by Swedish chemist John Gornlieb Gahn in 1774:
- Corrodes in moist air.
- Dissolves in acids.
- Melting point, 1245 degree C or 2271 °F.
- Boiling point, 2061 degree C or 3742 °F.
- Specific gravity of 7.4.
- Atomic weight, 54.968
- Manganese does not exist in free state, except in meteors.
- Manganese is distributed in all world in the form of ores, such as
 - Pyrolusite $\rightarrow$ magnet
 - Rhodochrosite
 - Franklinite
 - Psilomelane
 - manganite
- The word manganese come from Latin word 'magnes' meaning magnet.
- Manganese ranks about 12th in abundance among elements in Earth's crust.

Oxidation state of manganese

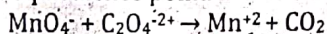
- +7 $\rightarrow \text{Mn}_2\text{O}_7$ and MnO_4^-
- +6 $\rightarrow \text{MnO}_3$, Manganic salt (H_2MnO_4) and manganates (K_2MnO_4)
- +4 $\rightarrow \text{MnO}_2$
- +3 $\rightarrow \text{H}_2\text{Mn}_2\text{O}_4$ and $\text{Mn}_2(\text{SO}_4)_3$
- +2 $\rightarrow [\text{Mn}(\text{H}_2\text{O}_6)^{2+}$, MnO , MnCO_3 , MnSO_4 , MnCl_2 .
- +3 $\rightarrow$ manganic compound
- +2 $\rightarrow$ manganous compounds

Potassium manganite (VII) as an oxidizing agent in organic chemistry

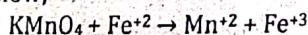
- Alkenes react with potassium manganite (VII) solution in cold.
- The colour change depends upon whether potassium manganite (VII) is used under acidic condition or alkaline condition.
- Under acidic condition manganite (VII) is reduced to manganese (II) ions.
- Under basic condition the manganite (VII) are first reduced to green manganite (VI) ions and then to dark brown solid manganese (IV) oxide or manganese oxide.
- 7 → 6 (dark green solution)
- 6 → 4 (dark brown precipitate)

Potassium manganite (VII) as an oxidizing agent in titration

- KMnO_4 is a strong oxidizing agent with intense dark purple colour.
- During reduction the purple permanganate ion changes into colourless Mn^{+2} ion.
- The solution turns from dark purple to faint pink colour at equivalence point.



- No addition indicator is used in this titration because KMnO_4 acts itself as an indicator.
- KMnO_4 solution is used to find the concentration of Fe(II) ions in a solution. The redox reaction is given below;



Iron

- Atomic number 26
- Complexes are; $[\text{Fe}(\text{H}_2\text{O})_6]^{+2}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{+3}$
- Iron (II) salts → pale green
- Iron (III) salts → yellow or brown
- Iron is used to catalyse the synthesis of ammonia through Haber's process.

Ores

- Red haematite → Fe_2O_3
- Brown haematite or limonite → $2\text{FeO} \cdot \text{O}_3 \cdot \text{H}_2\text{O}$
- Magnetite → Fe_3O_4

Varieties of iron

- Malleable or Wrought iron → 0.1 – 0.25 %
- Steel → 0.25–2 %
- Cast or pig iron → 2–3 %

Oxidation states of iron

- +2 → Ferrous → pale green
- +3 → Ferric → yellow or yellow brown

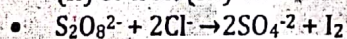
- +2 very easily oxidize to ferric ion.
- Even traces of dissolved oxygen in solution will accomplish oxidation of +2 to +3.
- When ferrocyanide added to solution containing ferric ions, a precipitate known as Prussian blue is $[\text{Fe}(\text{CN})_6]_2$ formed.
- Most +3 oxidation solutions are yellow or yellow brown due to formation of $[\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}$.

Iron as catalyst in Haber process

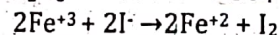
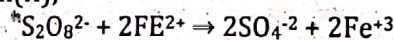
- $\text{N}_2 + \text{H}_2 \rightarrow \text{N}_2\text{H}_2 \rightarrow$ highly endothermic reaction
- $\text{N}_2\text{H}_2 + \text{H}_2 \rightarrow \text{N}_2\text{H}_4$
- $\text{N}_2\text{H}_4 + \text{H}_2 \rightarrow 2\text{NH}_3$
- $\text{N}_2\text{H}_2 \rightarrow$ highly unstable
- The hydrogen and nitrogen are absorbed on metallic iron surface.
- Splitting of N_2 into @N is slowest step and so limits the rate of entire process.
- $\text{N} + \text{H} \rightarrow \text{NH}$
- $\text{NH} + \text{H} \rightarrow \text{NH}_2$
- $\text{NH}_2 + \text{H} \rightarrow \text{NH}_3$

Iron ions in the reaction between persulphate ions and iodide ions

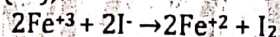
- The reaction between persulphate ion and iodide ions in solution can be catalyzed using either iron (II) or iron (III) ions.



- For Iron(II);



- For Iron(III);



Reaction of Hexaaqua iron(II) Hexaaqua iron (III) with water and ammonia

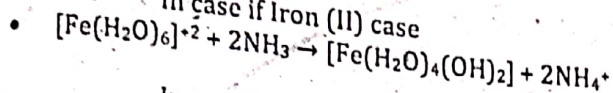
- Any hexaaqua complex ions undergo acid base reaction with water to produce a solution of pH less than seven.
- These are not redox reaction because during the reaction no change in the oxidation state of central metal occurs.
- In case if Iron (II) case
- $[\text{Fe}(\text{H}_2\text{O})_6]^{+2} + \text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{+1} + \text{H}_3\text{O}^+$
- In case if Iron (III) case
- $[\text{Fe}(\text{H}_2\text{O})_6]^{+3} + \text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{+2} + \text{H}_3\text{O}^+$
- Ferric gives more acidic solution than ferrous ions. (+3 > +2)
- In case of alkaline solution OH^- solution ions remove H_3O^+ ions and equilibrium shifts forward and more H^+ are lost from the complex in stages until a precipitate is formed.
- $[\text{Fe}(\text{H}_2\text{O})_6]^{+3} + 3\text{OH}^- \rightarrow [\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]^0 + 3\text{H}_2\text{O}$

- In case of Fe (II) complex the reaction in alkaline solution does not proceed because is energetically unfavorable.

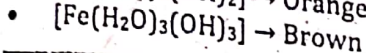
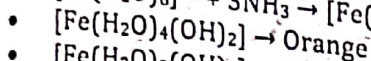
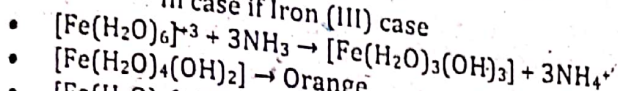
Reaction of Hexaaqua iron (II) and hexaaqua iron (III) with ammonia

- Ammonia can act both as a base and a ligand.
- Here ammonia simply act as a base, removing H⁺ from the complex.

In case if Iron (II) case



In case if Iron (III) case



Reactions of the iron with carbonate ions

- In case of iron (II)
- $\text{Fe}^{2+} + \text{CO}_3^{2-} \rightarrow \text{FeCO}_3$

In case of iron (III)

- The hexa aquairon (III) ion is sufficiently acidic to react with the weakly basic carbonate ion.
- If you add sodium carbonate solution to a solution of hexa aquairon (III) ions, you get exactly the same precipitate as if you added sodium hydroxide solution of ammonia solution.
- $2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow [\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{CO}_2 + 3\text{H}_2\text{O}$

Testing for iron (III) ions with thiocyanate ions

- This provide an extremely sensitive test for iron (III) presence in solution.
- If you add thiocyanate ions, SCN⁻ to a solution containing iron (III) ions, you will get an intense red solution containing the ion $[\text{Fe}(\text{SCN}(\text{H}_2\text{O})_5)]^{2+}$.
- $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + \text{SCN}^- \rightarrow [\text{Fe}(\text{SCN})(\text{H}_2\text{O})_5]^{2+}$

Copper

- Brownish red
- Atomic number 29
- The word is copper is derived from Cyprus.

Ores

- Malachite $\rightarrow \text{CuCO}_3\text{Cu}(\text{OH})_2$
- Azurite $\rightarrow 2 \text{CuCO}_3\text{Cu}(\text{OH})_2$
- Chalcocite $\rightarrow \text{Cu}_2\text{S}$
- Copper pyrite $\rightarrow \text{CuFeS}_2$

Oxidation States

- +1 $\rightarrow$ Diamagnetic $\rightarrow$ colourless $\rightarrow \text{Cu}_2\text{O}$, CuCl, CuBr
- +2 $\rightarrow$ cupric compound $\rightarrow$ Coloured $\rightarrow \text{CuO}$, CuF_2 , CuCl_2 , CuCO_3 , CuSO_4 .
- +3 $\rightarrow$ found in oxides $\rightarrow \text{KCuO}_2$, a blue black solid.
- Indeed, both copper (III) and even copper (IV) fluorides are known, K_3CuF_6 and Cs_2CuF_6 , respectively.
- In solid compounds copper (I) is often more stable at moderate temperature.
- The copper (II) ion is usually more stable in aqueous solution.
- Compounds of +2 copper are called cupric compounds.
- The best studied copper (III) compounds are the cuprate superconductors.
- Yttrium barium copper oxide ($\text{YBa}_2\text{Cu}_3\text{O}_7$) consists of both Cu(II) and Cu(III) centres.
- Like oxide, fluoride is a highly basic anion and is known as to stabilize metal ions in high oxidation states.

Reactions of Hexaaqua copper (II) ions with hydroxide ions

- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$
- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} \rightarrow$ blue solution
- $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] \rightarrow$ blue ppt
- Medium $\rightarrow$ neutral

Reactions of Hexaaqua copper (II) ions with ammonia

- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$
- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} \rightarrow$ blue solution
- $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] \rightarrow$ blue ppt
- The ppt dissolves in the presence of excess ammonia
- $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 4\text{NH}_3 + 2\text{OH}^- + 2\text{H}_2\text{O}$

Reactions of Hexaaqua copper (II) ions with carbonate

- The Hexaaqua copper (II) are not strongly acidic enough to release CO_2 from carbonates.
- $\text{Cu}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CuCO}_3$

- Different metals are known for their specific colour
- Cobalt (II) nitrate $\rightarrow$ red
- $\text{K}_2\text{Cr}_2\text{O}_7 \rightarrow$ orange
- $\text{KCrO}_4 \rightarrow$ yellow

- Nickel (II) chloride $\rightarrow$ green
- $\text{KMnO}_4 \rightarrow$ red
- White titanium oxide is an important ingredient in white paint.

CHAP NO.15 ORGANIC COMPOUNDS

- Organic chemistry deals with carbon based compounds.
- The word organic means life or living.
- In 1928, Friedrich Wohler synthesized urea from ammonium cyanate.

The compounds which contain carbon but not organic are:

- Carbon containing alloys
- Simple oxides of carbon
- Allotropes of carbon
- Metal carbonates
- Bicarbonates
- Carbonyls
- Cyanides
- Cyanates
- Sulfides

Major sources of organic compounds are:

- Fossil remains
- Petroleum
- Natural gas
- Coal occurs in rock strata in layers called coal beds.
- Coal formation:
Wood $\rightarrow$ Peat $\rightarrow$ Coal

Coal exists in different forms like:

- Lignite (low C %)
- Sub-bituminous coal
- Bituminous coal
- Anthracite (high C %)
- Coal is major source of aromatic compounds.
- Petroleum means crude oil
- Petroleum is also called mineral oil/ crude oil/ liquid gold.
- Petroleum includes only crude oil in strict sense.
- Petroleum includes both crude oil and natural gas in common sense.
- Natural gas and petroleum are found in association with each other.
- Anticancer agent palliate (Taxol) are obtained from yew tree.

- Antimalarial agent artemisinin are obtained from *Artemisia annua*.
- The study of processes and chemical reaction by which organic compounds are made are called Synthetic organic chemistry.
- An intermediate product of a reaction is used to synthesize a target process is called partial synthesis.
- Sometime the starting material converts through many steps into targeted products. Such process is called total synthesis.
- Urea process of Friedrich was commercialized for the first time by Gustaf Kompa from the synthesis of camphor in 1913.

Some products of Biotechnology:

- Benzylpenicillin $\rightarrow$ an antibiotic
- Insulin $\rightarrow$ A hormone
- Polyhydroxybutyrate $\rightarrow$ A Biodegradable thermoplastics
- Renin $\rightarrow$ an enzyme $\square$ Chemosensory protein (CSP)

Destructive distillation of coal:

- Coke $\rightarrow$ a reducing agent
- Coal tar $\rightarrow$ used for fertilizer making
- Coal gas
- Ammoniacal liquor $\rightarrow$ mixture of hydrogen and carbon monoxide

- Coal gas is also called town gas.
- Coal is converted to petroleum by Fischer-Tropsch process.
- A hydrogen and carbon monoxide is converted into alkane by Fischer-Tropsch process.
- The conversion of source of carbon into gaseous reactants like CO and H_2 in Fischer-Tropsch plant is called Gasification.
- The self-linkage of carbon atom to form chains and ring compounds is called Catenation.
- Two or more compound having same molecular formula but different structural formula is called isomers and this property is called isomerism.

Characteristics of organic compounds are:

- Unique properties of carbon like catenation.

- Isomerism
- None-ionic character
- Solubility
- Rates of organic reactions
- Similar structural features and behavior
- The mostly bonds of organic compounds are covalent which are none-polar.
- Most of organic compounds are insoluble in water but soluble in none-polar solvents.
- The organic reactions are slow because they involves breaking of some bonds and formation of new bonds.

Life molecules includes:

1. Proteins
2. Nucleic acids
3. Enzymes
4. Fats
5. Lipids etc

- Many farmers in USA grow maize for ethanol.
- Quinine → antimalarial
- Aspirine → cardiac disease and pain killer
- Borneol → anti-inflammatory
- Benzyl benzoate → scabicide
- Galantamine hydrobromide → alzheimer's disease
- The first fullerenes was discovered in 1885 by Herold Kroto, James Heath, Sean O'Brien, Robert Curl and Richard Smalley.
- In 2010, fullerenes were also discovered in outer space.

Some fullerenes are:

- C_{20}
- C_{60}
- C_{70}
- C_{76}
- C_{84}

→ Smallest is C_{20} but most common is C_{60} .

- Benzene ring is present in aromatic compound.

Organic compound types are**☐ Hydrocarbons**

1. Alkane
2. Alkene
3. alkynes

☐ Derivatives of hydrocarbons

1. Alkyl halide
2. Alcohol
3. Phenol
4. Ether
5. Ketones
6. Carboxylic acids

7. Aldehydes etc

- An atom or group of atom that gives certain characteristics properties to an organic compound is called a functional group.
- Functional group is chemically active part of molecule.
- A series of organic compounds that are differ by methylene group and have same structural and chemical characteristics are called homologous series.
- Alkane → C_nH_{2n+2}
- Cycloalkanes → C_nH_{2n}
- Alkenes → C_nH_{2n}
- Alkynes → C_nH_{2n-2}
- Alkyl → C_nH_{2n+1}

Characteristics of homologous series:

- Each series have its own formula.
- Members of series have same chemical properties.
- Series members have same method of preparation.
- Physical properties increase with increase in molecular mass.
- Extract sodium test or Lassaign's solution(L.S) is prepared by heating the substance with sodium metal in fusion tube till tube become hot and after cooling its filtered.

Detections tests

- Detection of Carbon in organic compounds
 $O.C + CuO \rightarrow CO_2$
 $CO_2 + Ca(OH)_2 \rightarrow CaCO_3$ **milky colour**
- Detection of Hydrogen in organic compounds
 $O.C + CuO \rightarrow H_2O$
 $H_2O + CuSO_4 \rightarrow CuSO_4 \cdot 5H_2O$ **blue colour**
- Detection of Nitrogen in organic compounds
 $L.S + NaOH + FeSO_4$ boil-cool + $FeCl_3 + HCl/H_2SO_4$
prussian blue or green colour
- Detection of Sulphur
 $L.S + \text{acetic acid} + \text{lead acetate}$ **black ppt of lead sulphide**
- Detection of Halogens in organic compounds $L.S + \text{conc nitric acid} + \text{silver nitrate solution} \rightarrow$
 - ✓ White ppt soluble in ammonium hydroxide indicate Chlorine
 - ✓ Yellow ppt slightly soluble in ammonium hydroxide indicate Bromine
 - ✓ Deep yellow ppt insoluble in ammonium hydroxide indicate Iodine
- Detection of Oxygen in organic compounds
 - ✓ Can't be test directly

✓ Tests for oxygen containing functional group.

✓ Formation of water in nitrogen atmosphere
✓ Combustion analysis

CHAP# 16 HYDROCARBONS

- Hydrocarbons are organic compounds that contain carbon and hydrogen only.
- Petroleum, natural gas and coal are main natural sources of hydrocarbons.
- The parent member of aromatic hydrocarbons are benzene.
- The formula of benzene is C_6H_6 .
- Unsaturated hydrocarbons containing double bond are called alkenes.
- Unsaturated hydrocarbons containing triple bond are called alkynes.
- Saturated cyclic hydrocarbon are called cycloalkanes.
- Unsaturated cyclic hydrocarbons are called cycloalkenes and cycloalkynes.
- The systematic process of naming of compound is called nomenclature.
- Some common names or trivial names of compounds are:
 - $HCOOH \rightarrow$ Formic Acid
 - $CH_3COOH \rightarrow$ Acetic Acid
- International union of pure and applied chemistry in 1957 set rules for symmetric names of organic compounds on the basis on structure. This is known is IUPAC system of nomenclature.
- The prefix n is used for organic compound having continuous chain.
- The prefix iso is used for those alkanes having attached methyl group to second last carbon.
- The prefix neo is used before alkane having two methyl groups attached to second last carbon atom.
- Cyclopropane is represented by a triangle.
- Cyclobutane is represented by a square.
- Cyclopentane is represented by a pentagon.
- Cyclohexane is represented by a hexagon.
- The ring is taken is substituent in naming cycloalkanes if it contain less carbon atoms than straight chain attached carbons.
- First four cycloalkanes are colourless gases.
- $C_5 - C_{17}$ are colourless liquids.
- Onward from C_{17} , alkanes are wax like soft solids.
- Alkanes are none-polar so insoluble in water.
- Alkanes are soluble in CCl_4 and C_6H_6 .
- B.P of alkanes increases with molecular weight.
 - $\rightarrow$ Propane > Ethane > Methane
 - $\rightarrow$ Decane > Noneane > Octane
- Straight chain alkane have high B.P than isomeric branch chain
 - $\rightarrow$ pentane > iso-pentane
 - $\rightarrow$ hexane > iso hexane > neo-hexane
- Melting point of alkane increase with molecular weight.
 - $\rightarrow$ Propane > Ethane > Methane
 - $\rightarrow$ Decane > Noneane > Octane
- There is no regularity in the melting point of alkane with the no of carbon atoms in molecule.
- The specific gravity of alkanes normally increase with molecular weight.
- Viscosity of alkanes increase with increase in no of carbon atoms.
 - $\rightarrow$ Propane > Ethane > Methane
 - $\rightarrow$ Decane > Noneane > Octane
- Cyclopropane and cyclobutane are gases while rest of cycloalkanes are liquids.
- Melting point and boiling point of cycloalkanes increase with increase in no of carbon atoms.
- Hybridization in alkane is sp^3 . Hybridization in alkene is sp^2 .
- Hybridization in alkyne is sp .
- Angle in alkane is 109.5°
- Angle in alkene is 120° .
- Angle in alkyne is 180° .
- The geometry of alkane is tetrahedral.
- The geometry of alkene is planar.
- The geometry of alkyne is linear.
- The deviation of normal tetrahedral angle of 109.5° to 60° is called angle strain.
- Distance between carbon carbon single bond is $1.54 \text{ \AA}$.
- Distance between carbon carbon double bond is $1.34 \text{ \AA}$.
- Distance between carbon carbon triple bond is $1.19 \text{ \AA}$.
- Distance between carbon Hydrogen single bond is $1.09 \text{ \AA}$.
- Alkanes are also called Paraffins (little affinity).

- Alkenes are also called Olefins.
- Alkynes are also called Acetylenes.
- Electronegativity of carbon is 2.5.
- Electronegativity of hydrogen is 2.1.
- Cyclopropane and cyclobutane have greater angle strain and hence undergoes ring opening reactions.
- Cyclopropane undergo ring opening reaction with H_2/Ni and HBr to give open chain products.
- Cyclobutane undergo ring opening reaction under severe conditions.
- Stability of cycloalkanes:
 $\rightarrow$ cyclohexane > cyclopentane > cyclobutane > cyclopropane
- A substituent reaction can be initiated by
 - Nucleophile
 - Electrophile
 - Free radical
- The product of homolytic bond fission are free radicals.
- The product of heterolytic bond fissions are ions.
- Electrophile can accept an electron pair.
- Nucleophile can donate lone pair of electron.
- An electrophile may be positive ion are neutral molecules with electron deficient centre.
- A nucleophile may be negative are neutral molecule with lone pair of electrons.
- Substitution reactions, which are initiated by free radical are called free radical substitution reaction.
- Example of substitution reaction by radical are chlorination of methane and ethane.
- In chlorination of methane, if Cl_2 is taken in excess, the major product will CCl_4 .
- In chlorination of methane, if Cl_2 is taken in limited, the major product will CH_3Cl .
- Combustion of methane gives 890.95 kJ/mol .
- Combustion of ethane gives 1559 kJ/mol .
- Along with water molecule combustion of ethane in
 - sufficient O_2 gives CO_2
 - limited O_2 gives CO
 - very limited O_2 gives C
- Lower members of alkenes gives oily product on treatment with chlorine or bromine.
- In common system alkenes are named as alkylene.
- In IUPAC system alkenes are named as alkanes.
- Energy released by combustions;
 - 1-butene $\rightarrow 2719 \text{ kJ/mol}$
 - Cis-2-butene $\rightarrow 2712 \text{ kJ/mol}$
 - Trans-2-butene $\rightarrow 2707 \text{ kJ/mol}$ & Isobutylene $\rightarrow 2703 \text{ kJ/mol}$
- Stability of Butene are as:
 - $\rightarrow 1\text{-butene} < \text{cis-2-butene} < \text{trans-2-butene} < \text{Isobutylene}$
- Greater no of alkyl groups attached, greater is the stability of alkenes. isobutylene is more stable than 1-butene
- Dehydration of alcohol at 1700°C in presence of sulphuric acid gives alkene.
- Dehydrohalogenation of alkyl halide in presence of alcoholic solution of $KOH/NaOH$ gives alkene and alkyl halide.
- The hydrogenation of alkenes is industrially used for the conversion of vegetable oils into ghee.
- Hydrogenation of alkene is done at $200\text{-}250^\circ \text{C}$.
- Hydrohalogenation of alkenes gives alkyl halide.
 141. The order of reactivity of halogens are
 $\rightarrow F_2 > Cl_2 > Br_2 > I_2$
- The reactivity of halogen acids are
 $\rightarrow HI > HBr > HCl > HF$
- Markovnikov's Rule: when polar reagent is added to unsymmetrical alkene, the positive part of reagent attaches itself to that carbon atom involved in the double bond holding greater no of hydrogen atoms. ($+ \rightarrow H$ or $H \rightarrow$)
- The major product of propene with HBr is 2-Bromopropane not 1-Bromopropane.
- Alkenes react with H_2SO_4 to produce hydrogen sulphates, which on hydrolysis yields alcohol at 100°C .
- Alkenes react with halogens in presence in presence of inert solvent like CCl_4 forms dihaloalkanes (vicinal dihalides).
- The bromination of alkenes provides a useful test for the presence of double bond.
- The colour of bromine rapidly discharge as the colourless dibromo compound is formed.
- Alkene react with hypohalous acids ($X-OH$) to form halohydrins.
- Halohydrins are organic compound having hydroxyl group and halogen at adjacent carbon atom.
- Alkenes react with oxygen in the presence of silver catalyst at temperature 300°C to epoxides.
- Epoxides on acid hydrolysis produce glycol.
- When ozone is passed through alkene in presence of inert solvent like CCl_4 to form ozonide.
- Ozonide are being explosive cannot be isolated.
- Ozonide on treatment with Zn and water cleavage at position of double bond to form carbonyl compounds.
- Ozonolysis is done for locating the position of the double bond in unknown alkene.

*(BSTI)

- The process by which simple molecules chemically join together to form large molecules with high molecular weight, is called polymerization.
- Polyethylene are also known as polyethene.
- The temperature for polymerization of ethane is 100-300°C with pressure of 1K-2K atm.
- Conjugated molecules are those compounds in which the carbon atoms are linked together by alternating single and double bonds 161.
Example of conjugated molecules are:
 - 1,3-butadiene
 - Benzene
- The C-C single bond in 1,3-Butadiene are 1.48 Å not 1.54 Å. 163. The C=C double bond in 1,3-Butadiene are 1.37 Å not 1.33 Å 164. There are two main types of isomerism:
 - Structural isomerism
 - Chain isomerism or skeletal isomerism
 - Position isomerism
 - Functional group isomerism
 - Metamerism
 - tautomerism
 - Stereoisomerism
 - Geometric or cis-trans isomerism
 - Optical isomerism
- A structural feature within a molecule that is responsible for its chirality is called chiral centre, of the molecule.
- A carbon bonded to four different groups is called chiral carbon atom or asymmetric carbon atom. For example lactic acid.
- A molecule may not have a chiral atom but still be chiral.
- A molecule may have one chiral atom but still be achiral.
- Optical activity of a compound is measured by an instrument called polarimeter.
- Nicol prism made of calcite, CaCO_3 act as polarizer.
- Isomer that rotate the plane of polarized light to right or clockwise direction is called dextrorotatory isomer or + isomer.
- Isomer that rotate the plane of polarized light to left or anticlockwise direction is called levorotatory isomer or - isomer.
- Optical isomerism is type of isomerism in which the isomer differ in their interaction towards plane polarized light.
- Two mirror images of single compound that cannot be superimposed are called enantiomers of each other.
- Isomers have different configuration.
- Three dimensional arrangement of atoms in space is called configuration.
- The isomer having two same groups on one side of double bond is called cis isomer. *(cis=same)
- The isomer having two similar groups on opposite side of double bond is called trans isomer.
- Isomerism due to unequal distribution of carbon atoms on either side of functional group is called Metamerism.
- A special type of isomerism in which isomer are in dynamic equilibrium with each other is called Tautomerism.
- Functional group isomerism have same molecular formula but different structural formula.
- In common system, the first member of alkyne series are named as acetylene.
- Relative stability of alkynes depends on:
 - ✓ Position of triple bond
 - ✓ No of substituents
 - ✓ Nature of substituents
- Ethyne, propyne and butyne are gases.
- $\text{C}_5 - \text{C}_{12}$ alkynes are liquids and higher are solids at room temperature and pressure.
- All alkynes are odourless and colourless except acetyls.
- Acetylene has garlic like odour.
- Alkanes are insoluble in water.
- Alkynes are slightly soluble in water.
- The boiling point of alkyne is higher than corresponding alkane
 - pentyne > pentene
 - hexyne > 1-hexene
- The boiling point of alkynes increase with increase in no of carbon atoms.
 - Heptyne > Hexyne > Pentyne
 - Butyne > Propyne > Ethyne
- The melting point of alkynes did not show regular pattern.
- Alkenes are more denser than alkane and alkene.
- Compounds having two halogen atoms on adjacent carbon atoms are called vicinal dihalides.
- Vicinal dihalides when treated with alcoholic KOH followed by NaNH_2 in liquid ammonia forms alkynes.
- Dehydrohalogenation of tetrahalides leads to alkyne.
- Alkynes are less reactive than alkene.
- Which one of the following is more reactive?
 - Alkane
 - Alkene ←
 - Alkyne

- Alkynes in which the triple bond is present at the end of the chain is called terminal alkyne or 1-alkynes.
- Terminal alkyne and acetylene are acidic in nature.
- If acetylene or terminal alkyne is treated with solution of sodium amide (NaNH_2) in liquid ammonia, sodium acetylide is obtained.
- Acetylene and 1-alkyne react with ammoniacal solutions of cuprous chloride and silver nitrate to form acetylides and alkynides of these metals.
- Copper acetylide $\rightarrow$ red ppt (CAR)
- Silver acetylide $\rightarrow$ white ppt (SAW)
- Copper and silver acetylides are highly explosives in dry conditions. They are decomposed by acids such as HNO_3 to regenerate acetylene.
- Non-terminal alkynes can be distinguished from terminal alkynes by Cu_2Cl_2 and NH_4OH or $\text{Ag}(\text{NO}_3)_2$ and NH_4OH
- Addition reactions of alkynes are:
 - Hydrogenation $\rightarrow$ alkenes
 - Reduction by dissolving metal $\rightarrow$ alkynides/acetylides
 - Hydrohalogenation $\rightarrow$ haloalkane
 - Hydration $\rightarrow$ carbonyl compounds
 - Halogenation $\rightarrow$ tetrahaloalkane
 - Ozonolysis $\rightarrow$ ozonides $\rightarrow$ ketones $\rightarrow$ carboxylic acids
- Hydrogenation of alkynes leads to alkene and onward to form alkane the reaction is stopped by poisoning Pd catalyst with $\text{BaSO}_4 + \text{quinoline}$ (Lindlar's catalyst).
- 1-alkynes and terminal alkynes react with metals in liquid ammonia to form salts like alkynides or acetylides.
- Alkynes react with water in presence of mercuric acid or sulphuric acid to form carbonyl compounds,
 - Acetylene/ethyne $\rightarrow$ aldehyde
 - Propyne or higher $\rightarrow$ ketones
- Alkynes react with ozone to form ozonide.
- Ozonide may be decomposed by water to give ketones.
- Ketones are oxidized by H_2O_2 to form carbonyl compounds.
- Special names of benzene with attached substituent:
 - Toluene $\rightarrow \text{CH}_3$
 - Phenol $\rightarrow \text{OH}$
 - Aniline $\rightarrow \text{NH}_2$
 - Nitrobenzene $\rightarrow \text{NO}_2$
 - o-xylene, m-xylene, p-xylene $\rightarrow 2 \text{CH}_3$
 - Catechol, resorcinol, hydroquinone $\rightarrow 2\text{OH}$
 - Mesitylene $\rightarrow 3 \text{CH}_3$
 - Durene $\rightarrow 4 \text{CH}_3$
 - Naphthalene $\rightarrow 2$ benzene
 - Anthracene $\rightarrow 3$ benzene
- Benzene is colourless liquid at room temperature and pressure.
- Benzene has peculiar smell and burning tastes.
- 218. The specific gravity of benzene is 0.8788.
- M=benzene melts at 5.5°C and boils at 80.2°C .
- Benzene is highly inflammable.
- The representation of real structure as a weighted average of two or more contributing structures is called resonance.
- The hybridization of C in benzene is sp^2 .
- Benzene has 6 C-C and 6 C-H sigma bonds.
- Hydrogenation of
 - Cyclohexene evolves 120 kJ/mol
 - 1,3-cyclohexadiene gives 232 kJ/mol
 - 1,3,5-cyclohexatriene gives 208 kJ/mol
- The resonance energy of benzene is 152 kJ/mol. (320-208) due to unusual stability, benzene does not give addition reactions like those of alkenes.
- Benzene prefers to undergo electrophilic substitution reactions rather than addition reactions.
- The main types of reactions of benzene are:
 - Addition reactions
 - Electrophilic substitution reactions
 - Oxidation reactions
- Benzene is less reactive than alkene.
- Benzene reacts with hydrogen in the presence of Ni or Pt catalyst at 150°C , under high pressure to form cyclohexane.
- Benzene reacts with chlorine or bromine in the presence of ultraviolet light to form hexachloride.
- Benzene reacts with concentrated nitric acid in the presence of concentrated sulphuric acid at 60°C to form nitrobenzene.
- An electrophile NO_2^+ is produced by reaction of H_2SO_4 and HNO_3 .
- Benzene reacts with concentrated H_2SO_4 at 120°C or fuming H_2SO_4 at room temperature to give benzene sulphonic acid.
- Fuming sulphuric acid is concentrated sulphuric acid in which SO_3 has been dissolved.
- Electrophilic aromatic substitution reaction:
 - Nitration $\rightarrow$ nitrobenzene
 - Sulphonation $\rightarrow$ benzene sulphonic acid
 - Halogenation $\rightarrow$ halobenzene
 - Friedel-Crafts's acylation $\rightarrow$ alkyl benzene
 - Friedel-Crafts's acylation $\rightarrow$ aromatic ketones
- Treatment of benzene with n-propyl chloride gives isopropyl benzene rather than the expected n-propyl benzene.

- Benzene reacts with alkyl halides in the presence of $AlCl_3$ to form alkyl benzenes.
- Benzene reacts with acid halides in the presence of a Lewis acid catalyst ($AlCl_3$) to give aromatic ketones.

Effects of substitution of benzene:

- ✓ Directive or orientation effect
- ✓ Effect on reactivity of benzene ring

Ortho/para directing substituents		Meta directing substituents:
• OR	• CH_3	• CR
• OH	• C_2H_5	• COR
• NH_2	• C_6H_5	• CH
• NR_2	• halogens	• COH
• NHR	• (R groups)	• SO_3H

- Ortho/para directing groups are activators except halogens.
- Meta directing groups are deactivators.
- When phenol is nitrated, the reaction yield only the o-nitrophenol and p-nitrophenol in ratio of 53% and 47%.
- Using nitrated mixture (conc HNO_3 + conc H_2SO_4), benzene can be nitrated at $60^\circ C$ to form nitrobenzene.
- Dinitrobenzene is obtained if reaction is carried at $100^\circ C$.
- Trinitrobenzene is obtained by using mixture of fuming nitric acid and sulphuric acid at $100^\circ C$.
- Trinitrotoluene is widely used as a powerful explosives

CHAP# 17 ALKYL HALIDES

- Monohaloalkanes are usually called alkyl halides.
- The functional group of alkyl halides are halogens.
- The general formula of alkyl halides are $C_n H_{2n+1} X$.
- In common system alkyl halide are named as "alkyl halide".
- In IUPAC system, alkyl halide are named as derivative of alkane (1-chloro, 2-methyl propane).
- Methyl and ethyl halides are gases at room temperature.
- Alkyl halide upto C_{18} are colourless liquids.
- Alkyl halides are water insoluble.
- Alkyl halides have high boiling point than corresponding alkane.
- For a given alkyl group, the boiling point increase with increase of size of halogen atom.
- For given halogen atom the boiling point increase with increasing size of alkyl group.
- Reaction of halogen acids with alcohol gives alkyl halide and water.
- By the action of phosphorous trihalides on alcohol, alkyl halides are obtained.
- Phosphorous trihalides are produced in situ by the action of red phosphorus on halogen.
- By the action of thionyl chloride on alcohol, alkyl halides are produced along with HCl.
- Pyridine being base absorbs HCl after its production.
- Alkanes react with halogens in presence of uv light or at $400^\circ C$ to yield alkyl group.
- The reactive group of organic compound is alkyl halides.
- Order of strength of C-X bonds,
 $\rightarrow C-F > C-Cl > C-Br > C-I$
- Order of reactivity of alkyl halide,
 $\rightarrow R-F < R-Cl < R-Br < R-I$
- Greater the no of alkyl groups, greater is the stability of the carbocation.
- Tertiary carbocation is more stable than secondary and primary.
- Base has a species that have affinity for proton.
- Nucleophile has the ability to form bond with carbon atom.
- A base attack hydrogen atom in the elimination reaction.
- A nucleophile attacks carbon atom in the substitution reactions.
- Tertiary alkyl halide undergo unimolecular substitution (SN^1).
- Primary alkyl halides undergo bimolecular substitution (SN^2).
- Unimolecular substitution (SN^1) followed by tertiary alkyl halide in polar solvent.
- Bimolecular substitution (SN^2) followed by primary alkyl halide in non-polar solvent.
- If medium is polar for secondary alkyl halide the substitution will SN^1 . If it's non-polar the substitution will SN^2 .

- The group or species which leaves the substrate or which is being replaced by incoming entering group is called leaving group. It's also called nucleophile.
- Elimination reaction takes place in the presence of base.
- E^1 are followed by tertiary alkyl halide.
- E^2 are followed by primary alkyl halide.
- E^1 has double step reaction.
- E^2 has single step reaction.
- A stronger base will favour in elimination.
- A stronger nucleophile will favour substitution.
- Ethoxide is strong base.
- Anion of thioalcohol ($C_2H_5S^-$) is strong nucleophile.
- Crowding within molecules of substrate also generally favours elimination over substitution reaction.
- Alkyl groups stabilizes alkene more than the substitution product.
- All those organic compound that contain at least one carbon metal bond are called organometallic compound.
- Alkyl or aryl magnesium halides are commonly known as Grignard Reagents. 294.
- The general formula of Grignard reagents are $R-Mg-X$.
- Grignard reagents are prepared by action of alkyl or aryl halide on freshly prepared magnesium metal in the presence of anhydrous or dry ether.
- Grignard reagents cannot be isolated, therefore, it's ethereal solution is directly used in the synthetic reactions.
- Increasing size of alkyl or aryl group make the formation of Grignard reagents difficult. $\rightarrow I > Br > Cl$
- Alkyl or aryl magnesium fluorides are not known.
- Alkylbromides are most suitable for preparation of Grignard reagents because alkyl iodides are expensive.
- Characteristics reactions of Grignard reagents are nucleophilic substitution and nucleophilic addition reactions.
- Formaldehyde on reaction with Grignard reagents gives primary alcohol.
- Higher aldehyde on reaction with Grignard reagents gives secondary alcohol.
- Ketones on reaction with Grignard reagents gives tertiary alcohol.
- Grignard reagents react with esters to form carbonyl compounds.
- Grignard reagents react with ethyl formate gives secondary alcohol at the end.
- Grignard reagents on reaction with ethyl acetate to give tertiary alcohol.
- Grignard reagents reacts with CO_2 and forms carboxylic acids.
- Hemoglobin have iron while plants chlorophyll has Magnesium.
- Amines are important nitrogen containing organic compounds.
- Amines are derivatives of NH_3 in which one or more hydrogen group is replaced by one or more similar or different alkyl groups.
- The functional group of amine may be:
 NH_2 NH N
- On basis of number of alkyl groups directly bonded to nitrogen atom, amines may be primary, secondary and tertiary amines.
- Amines in common system are named as "Alkyl amine".
- In IUPAC naming, alkynes are named as substituent attached to alkane and named as "n-Aminoalkane".
- Lower molecular weight amines are generally gases or lower boiling liquids at room temperature.
- Amines has ammonia like smell.
- Amines have high boiling point than alkane due to hydrogen bonding.
- All primary secondary and tertiary amines have hydrogen bonding with water molecules.
- Only primary and secondary amine are able to form hydrogen bonding among their molecule.
- Molecules of tertiary amine can't form hydrogen bonding so its boiling point is lower than other.
- Boiling point trend: $ter < sec < pri$
- Amines have trigonal pyramidal shape.
- Amines are basic in nature due to lone pair of electron on nitrogen.
- Amine react with acids to form salts.
- Basicity is directly proportional to no of alkyl groups.
- Order of basicity: $R_3N > R_2NH > RNH_2 > NH_3$
- When $R-X$ is heated with alcoholic NH_3 , it yields a mixture of primary, secondary and tertiary amines and quaternary ammonium salt.
- The reaction of $R-X$ with alcoholic NH_3 is also called alkylation of ammonia.
- Primary amines are prepared by the reduction of nitro alkanes ($R-NO_2$) in the presence of "Pt/Pd/Ni or lithium aluminum hydride ($LiAlH_4$) in ether.
- When nitriles or alkyl cyanides ($R-CN$) are reduced they yield the corresponding primary amines.
- Primary amines are obtained when simple amides are reduced by lithium aluminum hydride in water.
- On the basis of lone pair on nitrogen, Amines act as nucleophilic reagent.

- The lone pair of nitrogen in amine are available to the electron deficient reagents called electrophiles.
- When primary amine are treated with alkyl halides, they produce a mixture of secondary, tertiary amines and quaternary ammonium salts.
- Primary amine react with aldehyde and ketones yielding condensation products called imines.
- Imines are also called Schiff's bases.
- Primary amines react with acid chloride or acid anhydride to produce Nsubstituent amides.
- Secondary amines react with acid chloride to N,N-disubstituted amides.
- Tertiary amine have no directly attached hydrogen therefore they do not react with acid chloride to produce amides.
- When primary aliphatic amines are treated with nitrous acid, they yield highly unstable diazonium salt.
- Nitrous acid being unstable acid is prepared in situ by the reaction of NaNO_2 and dil HCl.

CHAP#18 ALCOHOL, PHENOL AND ETHER

- Alcohols, phenols and ethers are derivatives of water.
- In alcohol one H of water has been replaced by alkyl group.
- In phenol one H of water has been replaced by aromatic ring.
- In ether both H of water has been replaced by two alkyl groups.

Water	HOH
Alcohol	R-OH
Phenol	Ar-OH
Ether	R-O-R

- The general formula of alcohol is $\text{C}_n\text{H}_{2n+1}\text{OH}$.
- Alcohol may be monohydric, dihydric or polyhydric.
- Dihydric alcohol (diols) are usually called glycols because of sweet taste.
- In common system, alcohol are named as "n/sec/ter Alkyl alcohols".
- In IUPAC system, "e" of alkane is replaced by "ol". (alkane $\rightarrow$ alkanol).
- Lower alcohols are colourless, toxic liquids.
- Alcohols have characteristics sweet smell.
- Boiling point of alcohol is higher than alkane due to hydrogen bonding.
- Boiling point of alcohol increase regularly with the increase in the number of carbon atoms.
- Among isomeric alcohols, as the branching increases, the boiling point decreases.
- C_4 are completely soluble in water in all proportions.
- Angle in water is 109.5°C .
- Angle in alcohol is 109°C .
- The structure of alcohol and water is angular.
- Alcohols are acidic in nature.

- The O-H bond in alcohol is polar due to difference in E.N of two atoms.
- Alcohols are less acidic than water because alcohols have electron donating groups.
- The R groups in alcohol increase negative charge of oxygen so loss of hydrogen become difficult.
- Order of acidity of alcohols: pri > sec > ter
- Alcohols are not acidic enough to react with aqueous NaOH or KOH.
- $\text{R-OH} + \text{NaOH} \rightarrow \text{No Reaction}$.
- Alkenes react with concentrated sulphuric acid to produce alkyl hydrogen sulphates, which on hydrolysis yields alcohols.
- Alcohols can be prepared by hydrolysis of alkyl halides by means of water or an aqueous alkali.
- Formaldehyde react with Grignard reagent to produce primary alcohol.
- Aldehyde react with Grignard reagent to give secondary alcohol.
- Ketones react with Grignard reagent to produce tertiary alcohols.
- Reduction of aldehyde and ketone to alcohol is done at 200°C and 10atm.
- Formate esters on reaction with Grignard reagent secondary alcohol while other esters form tertiary alcohol.
- Both carboxylic acid and esters can be reduced to primary alcohols with Li Al H_4 .
- Carboxylic acid cannot be reduced with H_2/Ni or $\text{Na} + \text{C}_2\text{H}_5 - \text{OH}$
- The reactions of alcohol may be substitution reaction or elimination reactions.
- Alcohols react with halogen acids to form corresponding alkyl halides.
- Order of reactivity:

- $\text{HI} > \text{HBr} > \text{HCl}$
- $\text{Ter} > \text{sec} > \text{pri}$ (alcohols)
- HCl react only in the presence of catalyst (anhydrous ZnCl_2).
- Lucas test: in Lucas test, alcohols are treated with a solution of HCl and ZnCl_2 to form alkyl halides.
 - Tertiary alcohols react with Lucas reagent immediately.
 - Secondary alcohols react with Lucas reagent slower.
 - Primary alcohols react with Lucas reagent more slowly.
- Alcohols react with thionyl chloride to form alkyl chlorides.
- Phosphorus Trihalides also form alkyl halides with alcohols.
- Alcohols when treated with concentrated sulphuric acid at 170°C undergo dehydration to form alkenes.
- Alcohols react with carboxylic acid to form esters (RCOOR). This process is called Esterification.
- In Esterification, concentrated H_2SO_4 is used as catalyst.
- The reaction of Esterification is reversible
- Using strong oxidizing agent such as " $\text{Na}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{SO}_4$ " or " $\text{KMnO}_4 + \text{H}_2\text{SO}_4$ ", alcohols can be oxidized to carbonyl compounds and finally to acids.
- Primary alcohols are first oxidized to aldehydes and then to acids. 394. Secondary alcohols are first oxidized to ketone and then to carboxylic acids 395. Tertiary alcohols are stable to oxidation under normal conditions.
- Ethylene glycol when treated with acidic KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$ results in the formation of formic acid.
- Ethylene glycol when treated with periodic acid (HIO_4) or lead tetra acetate ($(\text{C}_2\text{H}_5\text{COO})_4\text{Pb}$), ethylene glycol gives formaldehyde.
- The sulphur analogues of alcohols are called Thiols and are called Thiols or alkyl hydrogen sulphides or Mercaptans.
- The functional group of thiols is $-\text{SH}$.
- Thiols react with insoluble salts and hence named as Mercaptans.
- Methanethiol is gas while ethanethiol and higher members are colourless, volatile liquids at STP.
- methanethiol and ethanethiol are added to natural gas in minute amounts to make gas leakage detectable by smell.
- Thiols have lower boiling point than alcohol due to lack of hydrogen bonding.
- Thiols are insoluble in water.
- The world phenol is used for specific compound "hydroxyl benzene".
- Phenols are usually named as derivatives of the parent phenol ($\text{C}_6\text{H}_5\text{OH}$).

- The C-O-H angle in phenol is 109.5° .
- The C-O-H angle in methanol is 108.5° .
- In phenol the six carbon atoms are sp^2 hybridized and internal angle is 120° .
- The C-O bond in phenol is slightly shorter than that of methanol.
- The C-O bond length in phenol is $1.36\text{\AA}$ and in methanol is 1.42° .
- Phenol are colourless liquids or low melting crystalline solids at room temperature.
- Phenols have characteristic odour.
- The vapours of phenol is itself toxic.
- The boiling point of phenol is slightly higher than that of alcohol due to strong hydrogen bonding.
- Phenol are more soluble than alcohol in water.
- Above 65°C , phenol and water are completely soluble.
- The liquid phenol containing 5% of water is known as carbolic acid. 421. Carbolic acid is used as disinfectant and germicide.
- **Acidity:** Carboxylic acid $>$ water $>$ phenol $>$ alcohol

	Pka	Ka
Carboxylic acid	5	10^{-5}
Water	7	10^{-7}
Phenol	10	10^{-10}
Alcohol	46-18	$10^{-16} - 10^{-18}$

- Being acidic, phenol reacts with NaOH or Na metal to form salt (Ar-ONa).
- Phenol can be prepared from benzene sulphonic acid.
- The sodium phenoxide is treated with dilute HCl to form phenol.
- Chlorobenzene is hydrolysed with aqueous NaOH at high temperature and pressure to form phenol. this process was developed by Dow company of USA in 1928.
- Cumene is also called isopropyl benzene.
- A solution of benzenediazonium chloride is warmed on a water bath at 50°C 429. Benzenediazonium chloride is prepared from aniline. 430.
- Phenol exhibits two types of reactions:
 - ☐ Reaction due to hydroxyl group
 - ☐ Reaction due to aromatic ring.
- The presence of OH group in phenol increases the reactivity of phenol.
- Phenol reacts with bromine water or aqueous bromine to give ppt of 2,4,6-tribromophenol.
- Chlorine reacts with phenol and forms:
 - ☐ O-Bromophenol 15%
 - ☐ P-Bromophenol 85%

- With dilute HNO_3 , phenol reacts to form ortho and para nitrophenol.
- 2,4,6-Trinitrophenol is also known as Picric acid.
- Phenol being acidic in nature, react with sodium metal to form salt with the release of H_2 gas.
- Phenol undergo oxidation with air (O_2) or chromic acid (CrO_3) to form pBenzoquinone.
- Compounds which contain a hydroxyl group in side chain attached to an aromatic ring are not phenols. they are called aromatic alcohols.
- The first person to demonstrate ether's use as anesthetic was Dr. Morton in 1896.
- The common home disinfectant is chlorine bleach.
- Chlorine bleach, a 5% solution of sodium hypochlorite.
- Antiseptics are antimicrobial substances that are applied to living tissues to reduce possibility of infection.
- All disinfectants which kill bacteria are called bactericidal.
- All disinfectants which kill fungi are called fungicidal.
- All disinfectants which kill bacteria spores are called sporicidal.
- All disinfectants which kill viruses are called virucidal.
- Ether are class of compound in which oxygen atom is linked to two alkyl groups or two aryl groups or one alkyl and one aryl group.
- The functional group of ether is C-O-C.
- Common naming of ether is "alkyl alkyl ether".
- IUPAC naming of ether: The larger alkyl group is taken for parent name and smaller alkyl group along with oxygen atom is named as alkoxy before the parent name such as "alkoxy, alkane".
- Symmetrical ethers are prepared by heating an excess of alcohol with concentrated H_2SO_4 at 140°C . if temperature is not favored higher than will lead to formation of alkene.
- In William synthesis, ether are prepared by treating sodium alkoxide with alkyl halide.
- Dimethyl ether and ethyl methyl ether are gases at STP, while others are colourless volatile liquids with pleasant odours.
- Ethers are highly inflammable.
- Ether have low boiling point than alcohol.
- Lower molecular ether are water soluble.
- Ethers are generally less denser than water.
- Ethers are quite stable they do not react with bases, active metals, oxidizing agents, reducing agents, they are also stable to dilute acids.
- Ethers form oxonium salts with strong concentrated acids.
- Ether donate a pair of electrons to hydrogen to form oxonium salts on reaction with cold concentrated HCl or H_2SO_4 .
- Ethers react with hot concentrated HI or HBr to form alcohol and alkyl halide. 462. Ethers react with acetyl chloride in the presence of anhydrous ZnCl_2 on heating to form alkyl chloride and ethyl acetate.

CHAP#19 CARBONYL COMPOUNDS 1: ALDEHYDES & KETONES

- ✓ A carbonyl group is functional group composed of carbon atom doubly bonded to an oxygen atom.
- ✓ Aldehyde have at least one hydrogen atom attached to carbonyl carbon.
- ✓ The functional group of aldehyde is formyl group or $-\text{CHO}$.
- ✓ In ketone the carbon atom is connected to two other carbon atoms.
- ✓ The ketone functional group is called keto group and is represented by $-\text{CO}-$.
- ✓ Common system naming of Aldehyde: their names derived from carboxylic acid containing same carbon atom but "ic acid" is replaced by aldehyde.
 - $\text{HCOOH} \rightarrow$ formic acid
 - $\text{HCHO} \rightarrow$ formaldehyde
- ✓ In IUPAC naming of aldehyde "e" of alkane is replaced by "al".
- $\text{CH}_4 \rightarrow$ Methane
- $\text{HCOH} \rightarrow$ Methanal
- ✓ In common naming system, ketone are named as "alkyl ketone".
- ✓ If two same groups are attached to carbonyl carbon, it's called symmetrical ketone.
- ✓ If two different groups are attached to carbon, it's called unsymmetrical carbon.
- ✓ In IUPAC naming of ketone "e" of alkane is replaced by "one" like
 - $\text{CH}_3\text{CH}_2\text{CH}_3 \rightarrow$ Propane
 - $\text{CH}_3\text{COCH}_3 \rightarrow$ Propanone
- ✓ The no of carbon at which oxygen is written before name of ketone like 2Pentanone.
- ✓ Formaldehyde is gas at room temperature while other aldehyde are colourless liquids.

- ✓ Acetone, the simplest ketone is liquid is room temperature with pleasant odour
- ✓ All the members of ketones are colourless liquids except acetone.
- ✓ Lower members of aldehyde and ketones upto C_4 are water soluble. Their solubility decreases as the size of the molecules increase.
- ✓ The most soluble in water is formaldehyde.
- ✓ Carbonyl compounds do not form hydrogen bonding with each other.
- ✓ Carbonyl compounds form hydrogen bonding with water molecule due to oxygen.
- ✓ Order of boiling point: alkane/ether < aldehyde/ketone < Alcohol
- ✓ The boiling point of aldehyde and ketone increase with increase in the molecular weight. Ethanol > Methanal.
- ✓ The carbon and oxygen of carbonyl group are sp^2 hybridized.
- ✓ The length of CO single bond is $1.43 \text{ \AA}$.
- ✓ The length of CO double bond is $1.23 \text{ \AA}$.
- ✓ Ozone react vigorously with alkene and form ozonide which is unstable.
- ✓ Ozonide is reduced directly to aldehydes and ketones by zinc and water. This reaction is called ozonolysis.
- ✓ Water adds to alkene in presence of mercuric sulphate and sulphuric acid to form enol which is unstable.
- ✓ The enol intermediate undergoes arrangement to form aldehydes and ketones depending on starting alkyne used.
- ✓ Friedel-Crafts acylation of aromatic gives aromatic ketones.
- ✓ When benzene is treated in the presence of Lewis acid, $AlCl_3$ with acid halide, an aromatic ketone is produced.
- ✓ The aldehydes and ketones undergoes addition reactions as compared to alkenes.
- ✓ The presence of base increase the nucleophilic character of the reagent.
- ✓ The presence of acid increase the electrophilic character of the carbonyl carbon atom inducing more positive charge on it and thus enhances its ability to be attacked by weak nucleophiles.
- ✓ Carbonyl compounds are weak Lewis bases which can be protonated.
- ✓ In addition reaction of carbonyl atom its geometry changes from trigonal to tetrahedral as its changes from sp^2 to sp^3 .
- ✓ An acid catalyzed reaction will take place with weak nucleophile.
- ✓ A base catalyzed addition reaction will take place with strong nucleophile. 505. Ketones are less reactive than aldehyde
- ✓ Ketone is less reactive than aldehyde due to
 - Steric Hindrance
 - Electronic effect
- ✓ An alkyl group neutralize positive charge on carbonyl atom decreasing its reactivity towards nucleophile.
- ✓ Addition of hydrogen to aldehyde and ketones is called reduction.
- ✓ Aldehydes and ketones can be reduced to saturated hydrocarbons by:
 - Clemmenson Reduction: by using Zinc amalgam and conc HCl
 - Wolf-Kishner method: by using hydrazine.
- ✓ Aldehydes and ketones are reduced to alkanes in the presence of Zinc amalgam and HCl as reducing agent.
- ✓ When aldehyde or ketone is treated with hydrazine (NH_2NH_2), alhydrazone is obtained.
- ✓ A hydrazine on heating with KOH in boiling with ethylene glycol gives corresponding alkanes.
- ✓ In Clemmenson-reduction and Wolf Kishner reduction, alkane is produced at the end.
- ✓ Aldehydes and ketones are easily reduced to primary and secondary alcohols respectively by using metal hydrides as reducing agents.
- ✓ The most common metals hydrides are Lithium aluminum hydride ($LiAlH_4$) and sodium borohydride ($NaBH_4$).
- ✓ Formaldehyde gives primary alcohol by reaction with Grignard Reagent.
- ✓ Reduction of aldehydes and ketones by using hydrocyanic acid is done in basic medium.
- ✓ Acetophenone react with hydrocyanic acid to form acetophenone cyanohydrin.
- ✓ Aldehydes react with ammonia to form solid aldehyde ammonia.
- ✓ Some important ammonia derivatives are:
 - Alkyl amine $R-(NH_2)$
 - Hydroxyl amine (NH_2OH)
 - Hydrazine (NH_2NH_2)
 - Phenyl hydrazine ($C_6H_5NHNH_2$)
- ✓ Primary amine react with aldehyde and ketone to form unstable compound which losses water to form product with CH double bond, called imines.
- ✓ Aldehydes and ketones form oxime on reaction with hydroxyl amine.
- ✓ Aldehyde and ketone react with hydrazine to form hydrazine.
- ✓ Alcohols are weak nucleophile, an acid catalyst (H_2SO_4) is used.
- ✓ Hemiacetal contain both alcohol and ether is functional group.
- ✓ Acetal have two ether functional group.
- ✓ Aldehydes are more easily oxidized than ketones.
- ✓ The hydrogen atom attached to carbonyl group in aldehyde is oxidized to OH group. ($RCHO \rightarrow RCOOH$)

- ✓ Aldehydes can be oxidized by much milder oxidizing agent such as:
 - Tollen's Reagent
 - Fehling's Solution
 - Benedict's Solution
- ✓ The Tollen's Reagent is ammonium silver nitrate ($2\text{Ag}(\text{NH}_3)_2\text{OH}$).
- ✓ Tollen's reagent reaction is also called mirror test.
- ✓ Ammonium carboxylate is formed by the reaction of aldehyde with ammonical silver nitrate.
- ✓ The Fehling's solution is $2\text{Cu}(\text{OH})_2 + \text{NaOH}$.

- ✓ If aldehyde react with Fehling's solution, the deep blue colour of cupric ion is reduced to red ppt of cupric oxide.
- ✓ Oxidation by Fehling solution is used widely for the estimation of glucose in blood and urine.
- ✓ Ketones having hydrogen attached to alkyl group or also called alpha carbon can be oxidized in the presence of $\text{K}_2\text{Cr}_2\text{O}_7 / \text{H}_2\text{SO}_4$, $\text{KMnO}_4 / \text{H}_2\text{SO}_4$ / conc HNO_3 etc which involves breaking C-C bond in case of unsymmetrical ketone, the carbonyl group remain smaller alkyl group as oxidation takes place at this site.

CHAP# 20 CARBONYL COMPOUNDS 2: CARBOXYLIC ACID AND FUNCTIONAL DERIVATIVES

- ✓ Carboxylic acid is organic compound which contain carboxyl group (COOH).
- ✓ The carboxyl group consist of carbonyl and hydroxyl group.
- ✓ Acid containing one carboxyl group is called mono carboxylic acids.
- ✓ Acid containing two carboxylic acids are called di carboxylic acids.
- ✓ Carboxylic acids may be aliphatic or aromatic.
- ✓ The general formula of aliphatic Carboxylic acid are RCOOH .
- ✓ The general formula of aliphatic carboxylic acids are ArCOOH .
- ✓ Aliphatic carboxylic acids are also commonly called fatty acids because esters of several higher members are fats.

Some derivatives of Carboxylic acid are:

- Acid halide/ Acyl halide
- Acid amide
- Ester
- Acid anhydride

Names of some carboxylic acid:

Formula	Name	Language	Word
HCOOH	Formic acid	Latin	Formica → ant
CH_3COOH	Acetic acid	Latin	Acetum → vinegar
$\text{CH}_3\text{CH}_2\text{COOH}$	Propionic acid	Greek	Protos, prion → first fat
$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	Butyric acid	Latin	Butyrum → fat

Nomenclature

- ✓ In IUPAC naming of carboxylic acid, "e" of alkane is replaced by "oic acid" like
 - $\text{HCOOH} \rightarrow$ Methanoic acid
 - $\text{CH}_3\text{COOH} \rightarrow$ Ethanoic acid
- ✓ Carboxylic acid containing two carboxyl groups are called dicarboxylic acids or dioic acids (IUPAC).

Properties

- ✓ The lower members of the aliphatic acids $\text{C}_1 - \text{C}_{10}$ are liquids with distinctive odours.
- ✓ Acetic acid which constitutes about 4-5% of vinegar has a characteristic smell which is recognizable in vinegar.
- ✓ Butyric acid is substance that can be smelled in rancid butter.
- ✓ Higher members of acid homologous series are wax-like solids.
- ✓ Anhydrous ethanoic acid freezes at 17°C to form a solid which look like ice. It is, therefore also known as glacial acetic acid.
- ✓ Carboxylic acid are more polar than alcohol.
- ✓ Solubility of carboxylic acid in water decreases as their relative molecular mass increases.

Structure

- ✓ The structural features of the carboxyl group are most apparent in formic acid.
- ✓ The bond length between C=O double bond is 120 pm. 561. The bond length between C-O single bond is 134 pm.
- ✓ The bond angles of H-C-O in carboxylic acids is 111°A .
- ✓ The bond angles of H-C=O in carboxylic acids is 124°A .

- ✓ The bond angle of $O=C=O$ in carboxylic acids is $125^\circ A$.
- ✓ The hybridization of hydroxyl oxygen in carboxylic acid is sp^2 .
- ✓ Lone pair from hydroxyl oxygen makes the carbonyl group less electrophilic than that of aldehyde and ketone.

Acidity

- ✓ Carboxylic acid is weak acid than mineral acids.
- ✓ Carboxylic acid is more acidic than water, phenol and alcohol.
- ✓ Monocarboxylic acid are monobasic acids.
- ✓ Any electron withdrawing substituent will tend to stabilize the carboxylate ion by dispersing its negative charge and thus increase the acidity of acid.
- ✓ Any electron donating group will tend to destabilize the carboxylate ion and thus decrease the acidity of the acid.
- ✓ Order of acidity; trichloro acetic acid > Dichloroacetic acid > chloro acetic acid > methanoic acid > Ethanoic acid > Propionic acid.
- ✓ Carboxylic acids can be prepared by the action of Grignard reagent with carbon dioxide.
- ✓ Reaction of carbon dioxide with Grignard reagent is known as carboxylation of Grignard reagent.
- ✓ The reaction that provide an extension to length of carbon chain is reaction of CO_2 with $R-Mg-X$.
- ✓ Compounds having cyanide ($-CN$) group are called alkyl nitriles or alkyl cyanides.
- ✓ The carbon nitrogen triple bond in alkyl nitriles can be hydrolyzed to carboxylic acid in aqueous acid medium.
- ✓ Primary alcohol can be oxidized to carboxylic acids by oxidizing agents like acidified potassium permanganate or potassium dichromate etc.
- ✓ Primary alcohol on oxidation, gives aldehyde which on further oxidation converts to carboxylic acid.
- ✓ Oxidation of aldehydes in the presence of oxidizing agents like $KMnO_4$, $K_2Cr_2O_7$ or Ag_2O gives carboxylic acid with the same number of carbon atoms.
- ✓ Aromatic carboxylic acids can be prepared by the oxidation of aliphatic side chain (alkyl group) present on the benzene ring, with oxidizing agent like $KMnO_4$, $K_2Cr_2O_7$. any side chain is converted to carboxyl group.
- ✓ In oxidation of alkyl benzene, the methyl group is oxidized not the aromatic ring, this show the striking stability of aromatic rings towards oxidizing agents.
- ✓ The carboxylic acid is named so because it contains both carboxyl group and hydroxyl group.
- ✓ Carbon atom of carboxylic acid is less positive than that of aldehyde and ketones so it did not undergoes addition or condensation reactions like that of aldehyde and ketone.
- ✓ The OH donate electron to CO in carboxylic acid and hence reduce its partial positive charge so it is not attacked by nucleophiles as compared to aldehyde and ketone.
- ✓ Acyl halides or acid halides are derivatives of carboxylic acids that are obtained by replacing OH of carboxylic acid by halogen atoms.
- ✓ The most reactive derivatives of carboxylic acid derivatives are alkyl halide.
- ✓ Acyl chloride are most common and less expensive than bromides and iodides.
- ✓ Alkyl chlorides can be prepared by the reaction of acids with thionyl chlorides or phosphorus pentachloride (PCl_5).
- ✓ Acid anhydrides are derived formic acids by removing water from two carboxylic acid molecules.
- ✓ Naming of acid anhydrides: the name of acid of carboxylic is replaced by anhydride like carboxylic acid $\rightarrow$ carboxylic anhydride.
 - $CH_3-CO-O-CO-CH_3$ acetic anhydride
- ✓ The most important and commercially available anhydride are acetic anhydride or ethanoic anhydride.
- ✓ The dehydrating agent is P_2O_5 .
- ✓ Esters are formed by replacing OH of acid by OR.
- ✓ While naming ester the R part of OR is named first and then followed by the name of the acids, where by "ic acid" is replaced by "ate".
 - Carboxylic acid $\rightarrow$ carboxylate
 - $CH_3-CO-OCH_3 \rightarrow$ methyl ethanoate (ethanoic acid)
- ✓ When a carboxylic acid and alcohol are heated in the presence of acid catalyst, an equilibrium is established with the formation of ester and water.
- ✓ Esterification is reaction of an acid with alcohol.
- ✓ Ethyl acetate is important ester which can be prepared by the reaction of acetic acid with ethanol.
- ✓ Esters can also be prepared by the reaction of an alcohol with acid halides or acid anhydride.
- ✓ Amides are least reactive derivative of acid which is formed by the replacement of OH of acid by NH_2 group.
- ✓ Amides are named by replacing "ic acid" corresponding acid by word "amide".
 - Carboxylic acid $\rightarrow$ carboxylamide
 - $H-CO-NH_2 \rightarrow$ formamide/Methanamide
 - $CH_3-CO-NH_2 \rightarrow$ acetamide/ Ethanamide
- ✓ Amides can be prepared by the reaction of ammonia with carboxylic acid to form first ammonium salts which on heating produces acid amides.

- ✓ Amides can also be prepared by the reaction of ammonia with ester or acetyl chloride.
- ✓ Order of acid derivatives towards nucleophile are: Acylhalide > acid anhydride > ester > amide > Nitrile $*(Cl-O-OR-NH_2-CN)$
- ✓ Acylhalide, acid anhydride, ester, amide and nitrile on hydrolysis yield corresponding carboxylic acid.
- ✓ Acylhalide and acid anhydride on reaction with alcohol yield ester.
- ✓ Acylhalide, acid anhydride and ester on ammonolysis yield an amide.
- ✓ Carboxylic acid can be reduced to the corresponding alcohols using lithium tetrahydrido aluminate in dry ethoxy ethane.
- ✓ The removal of carbon dioxide from a carboxylic acid takes place is known as decarboxylation.
- ✓ Decarboxylation of carboxylic acid takes place when its sodium salt is heated with soda lime to form alkanes.
- ✓ Soda lime is dry mixture of caustic soda, NaOH and quick lime CaO.
- ✓ Ascorbic acid occur naturally in fruit, used as preservatives.
- ✓ Ascorbic acid inhibits fungal growth but allow bacterial growth.
- ✓ Benzoic acid and sodium benzoate have inhibitory effect on the growth of yeast.
- ✓ The tartness in lemon is due to carboxylic acid.
- ✓ Oranges have citric acid.
- ✓ Acetic acid present in vinegar is responsible for giving sour taste.
- ✓ Malic acid found in unripe fruit gives these fruit a sour or tart taste.
- ✓ Acyl group react with benzene in the presence of lewis acid to form aromatic ketones.
- ✓ On hydrolysis, anhydrides form corresponding carboxylic acid.
- ✓ Hydrolysis of esters is called saponification.
- ✓ Hydrolysis of esters is used to make soaps from fats.
- ✓ Ester can be reduced to primary alcohol in the presence of reducing agent in ether which is used as solvent.
- ✓ Ester react with two equivalent of Grignard Reagent to give tertiary alcohol.
- ✓ Ester react with R-Mg-X to form ketone, ketone react with another R-Mg-X to form tertiary alcohols.
- ✓ Amides on hydrolysis form the corresponding carboxylic acids. This reaction is slow and requires acid or base as catalyst.
- ✓ Amides can be reduced to primary amine in presence of aluminium hydride.
- ✓ Alkyl nitriles or simply nitriles are also considered as derivatives of carboxylic acid.
- ✓ Alkyl nitriles can be obtained from carboxylic acids, through they do not contain acyl group.
- ✓ On boiling with a dilute minerals acid or dilute alkali, nitriles are hydrolysed forming carboxylic acids.
- ✓ Alkyl cyanide when treated with a reducing agent such as sodium and ethanol or lithium aluminium hydride (lithium tetra hydridoaluminate(III) in ethoxyethane, nitriles are primary reduced to amines.
- ✓ Nitriles on reaction with Grignard reagent produce Ketones.

Chap No. 21 BIOCHEMISTRY

Carbohydrates

- The major sources of carbohydrates which comprise upto 80% of their dry weight. In contrast animals contains very small amount of carbohydrates are about 1%.
- Carbohydrates include glucose (grape sugar), fructose (honey), starch (potatoes), cellulose (wood) and glycogen (liver) etc.
- Plants use these carbohydrates both as energy sources and as supporting materials while animals, use them for production of energy.
- Carbohydrates are the organic compounds of carbon, hydrogen and oxygen.
- Most of them can be represented by a general formula $C_n(H_2O)_n$ therefore, they were for the first time defined as the hydrates of carbon.
- however, there are some compounds which are carbohydrates but they do not conform to this general formula for example 2-deoxyribose having molecular formula $C_5H_{10}O_4$ cannot be represented by $C_n(H_2O)_n$ formula.
- On the other hand, there are also some compounds which follow this $C_n(H_2O)_n$ formula but they are not carbohydrates, for example formaldehyde CH_2O and acetic acid $C_2H_4O_2$.
- Carbohydrates are precisely defined as, the poly, hydroxy aldehydes or poly hydroxyketones or the

molecules which yield these compounds hydrolysis.

Classification of Carbohydrates:

On the basis of the number of simple sugar units presented molecules, carbohydrates are divided into three major classes. These are

- Monosaccharides
- Oligosaccharides
- Polysaccharides

1. Monosaccharides

- They are also called simple sugars. They contain only one sugar unit per molecule.
- They cannot be broken down into more simpler carbohydrates on hydrolysis.
- For example, glucose, fructose etc.
- The monosaccharides are again subdivided on the basis of the type of functional group and the number of carbon atoms in the molecule.
- On the basis of type of functional group monosaccharides may be classified as aldoses or ketoses.
- Similarly on the basis of number of carbon atom in a molecule monosaccharides may be trioses, tetroses, pentoses, hexoses.

2. Oligosaccharides

- These are those carbohydrates which contain 2-10 units of monosaccharides or simple sugars per molecule.
- They are hydrolysable carbohydrates.
- They are broken down into two to ten simpler carbohydrates or monosaccharides upon acid hydrolysis.
- Those oligosaccharides which contain two monosaccharide units per molecule are called disaccharides while those containing three and four units of monosaccharides per molecule are called trisaccharides and tetrasaccharides respectively.
- Upon hydrolysis they may yield similar or different types of monosaccharides.
- For example maltose yields the same kind of two glucose units upon hydrolysis.
- While sucrose yields two different types of monosaccharides. $\text{Sucrose} \rightarrow \text{glucose} + \text{fructose}$

Glycosidic Linkage or Bond:

- During the formation of a disaccharides the two monosaccharide units combine together by an oxygen atom with the elimination of one water

molecule. This type of linkage is called glycoside linkage or glycoside bond.

- This is shown as under. Similarly two glucose units combine by a glycosidic bond to form maltose

3. Polysaccharides:

- They are the complex class of carbohydrates.
- They contain more than ten (10) units of monosaccharides per molecule.
- They are also hydrolysable.
- Upon hydrolysis they yield a large number of similar or different kinds of monosaccharides.
- For example starch, cellulose, glycogen etc.

Functions of Carbohydrates:

- Basic function of carbohydrates is the production of energy for the performance of vital activities in living organisms.
- They are also known a "fuel of life". They produce energy by the process of oxidation.
- $\text{Carbohydrate} + \text{O}_2 \rightarrow \text{C}_2\text{O} + \text{H}_2\text{O} + \text{Energy}$.
- These are chief sources of energy and therefore spare proteins and lipids for other important functions of the body.
- Glucose is used as an immediate source of energy for the sick and sportsmen. It is also used in the manufacture of jams and sweets.
- Fructose is used as a sweetening agent in confectionery, in medicinal Syrup. It is also used to prevent sandiness in ice-creams.
- It is also used as a substitute of table sugar (sucrose) for the obese and the diabetic.
- Sucrose is used as a food and as ingredient of jams, jellies, confectionaries, syrup. It is also used in the preparation of sucrose.
- octaacetate which is used for the denaturation of alcohols and for making anhydrous adhesives.
- Starch is principally used as a food. It is industrially used for manufacturing of ethanol by the process of fermentation. It is also used as a stiffening agent in textile industry and in laundry. It is also used as an adhesive to fasten paper.
- Cellulose has no food value. But it is used as a roughage in our diet for promoting the peristaltic motion of digestive tract. It is used for the manufacturing of paper.
- Oligosaccharides are involved in the formation of secreted proteins like antibodies and blood clotting factors.
- The receptors on the cell membranes are the complexes of carbohydrates with certain proteins. The receptors are involved in molecular targeting or molecular recognition.
- The derivatives of carbohydrates such as protein glycol heparin sulfate are involved in the

attachment or adhesion of neurons to one another during the development of nervous system.

Role of Various Carbohydrates in Health and Diseases:

- There are different types of carbohydrates which are involved in the health and diseases of living beings. Some of these are given as under.
- Sucrose
- Glucose
- Lactose

1. Sucrose:

- Sucrose is a disaccharide. Since long, it has been used as a sweetening agent and as a source of production of energy for living organism.
- But the use of sucrose is the primary cause of tooth decay and obesity.
- The material known as "plaque" which sticks to our teeth is caused by sucrose.

2. Lactose:

- It is a disaccharide of glucose and galactose.
- It is also called milk sugar.
- It is found in the milk of mammals.
- Human milk contains about 6.8% while cow milk contains about 4.8% lactose.
- Lactose is digested by a special type of enzyme called lactase.
- Lactase is secreted by the intestinal mucosal cells of young mammals. Although milk is a universal food of new born mammals and one of the most complete human diet, still many human adults are unable to digest milk due to deficiency of lactase-intolerance.
- The general symptoms of this disease are abdominal bloating, cramps, flatulence, colic pains, abnormal intestinal flow, nausea and watery diarrhea. These symptoms appear within 30-90 minutes after the ingestion of milk.
- To avoid this disease fermented milk products such as yogurt and cheese should be consumed.

3. Glucose:

- It is the most common and popular monosaccharide that can be found in sweet fruits such as grapes, which contains 20-30 % glucose. It is mainly used by the living bodies for the production of instant energy.
- It is an important constituent of human blood.
- Human blood contains normally about 65-110 mg of glucose per 100ml.
- The surplus glucose is converted to a polymer called glycogen in human beings. Glycogen is then stored in the liver and muscles. When the

- body is deficient in glucose, this liver and muscle glycogen is
- hydrolyzed to glucose according to the body requirement.
- Human pancreas secretes a hormone known as insulin.
- Insulin helps in the metabolism of glucose to produce energy.
- In some cases defects in the metabolism of glucose occurs due to which blood glucose level rises from the normal level. This condition results in a disease known as diabetes mellitus.
- The consequences of unchecked diabetes include hardening of blood vessels, dysfunction of kidneys, diabetic coma which cause premature death.

Nutritional Importance:

- Carbohydrates are the most important energy containing nutrients for living organisms.
- Plant contains stored carbohydrates called starch while animals contain stored carbohydrates called glycogen. Both these polymers are broken down into the simplest monosaccharide units known as glucose before oxidation.
- Then glucose is oxidized in the body cells by different types of pathways (series of enzymatic chemical reactions) to release energy.
- This energy is stored in the form of molecules known as ATP (adenosine triphosphate) in the different parts of the body.
- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
- One mole of glucose on complete oxidation by citric acid cycle produces 36 ATPs.

Proteins:

- This term protein is derived from the Greek word proteios which means "first, prime or chief", as proteins are of primary importance as food source, in the tremendous variety of physiological functions they perform and as the object of genetically controlled synthesis.
- Proteins are complex nitrogenous organic compounds which are associated with the concept of life itself.
- By chemical composition, proteins are composed of carbon, hydrogen, oxygen and nitrogen.
- Percentage of nitrogen is fairly constant and is about 16% of the molecular weight of protein.
- Some proteins also contain smaller quantities of sulphur and phosphorous.
- Proteins are large molecules which are made up of smaller basic units called amino acids

- There are about 20 different amino acids which combine in different sequence and different numbers and produce an infinite number of different types of proteins.
- It is analogous to the infinite number of words which can be formed with 26 letters of the alphabets.
- The bacterium, *Escherichia coli* (*E. coli*) has been estimated to contain about 3000 different types of proteins.
- Similarly human organism contains about 100,000 different kinds of proteins. But none of the proteins of *E. coli* is identical with any of the human proteins.

Functions of proteins

- Proteins are the most abundant intra-cellular macromolecules and form more than 50% of the dry weight of most organisms.
- They are present in all animals, plants, bacteria and viruses.
- They act as catalysts in the shape of enzymes, as barriers such as skin and bacterial cell walls, as protective agents in immune system, as storage depots such as ferritin for iron storage in blood, as transport agent such as hemoglobin as oxygen carrier.
- They also act as receptors of chemically transmitted informations as well as the carrier of these information in the form of substances known as pheromones.
- They are also involved in the activities of muscles (contraction and relaxation) and in the transmission of heredity characters from parents to offsprings (in the form of genes).

Classification of Proteins:

Proteins have been classified into the following three major classes.

- Simple Proteins
- Compound or Conjugated Proteins
- Derived Proteins.

1. Simple Proteins:

- These are proteins which upon hydrolysis produce only simple amino acids or their derivatives.
- Examples of such proteins are Albumins, Globulins, Legumin, Collagen, Globins, Histones etc.

2. Conjugated Proteins:

- The proteins of this group are bonded or conjugated to some non proteins known as prosthetic groups. These are sub divided into the following types.
 - Conjugated Protein → Prosthetic group
 - Nucleoproteins → DNA or RNA
 - Phosphoproteins → Phosphoric acid
 - Lipoproteins → Lipids
 - Glycoproteins → Carbohydrates
 - Chromoprotein → Coloured compounds
 - Metalloproteins → Metals eg. Zn, Cu, Fe, Mn etc.

3. Derived proteins:

- These are proteins which are produced by the partial digestion of simple or conjugated proteins.
- They may be proteins, meta proteins, coagulated proteins etc.

Structure of Proteins:

- Proteins being very complicated macromolecules have very complicated structures.
- In short all the proteins appear in any of the following four different structures.
 - Primary structure
 - Secondary structure
 - Tertiary structure
 - Quaternary structures

1. Primary Structure:

- This structure shows the sequence and number of different amino acid units along the peptide chain.
- It also shows whether the polypeptide chain is open, branched or cyclic.

II. Secondary Structure:

- X-ray diffraction experiments have shown that long running polypeptide chains tend to twist or coil upon themselves in a special pattern.
- Secondary structure shows this folding of the polypeptide chain to form a specific coiled structure, held together by strong hydrogen bonding.
- Secondary structure may assume any of the following two different forms.
 - a) Alpha-helix form
 - b) B-pleated sheets.

III. Tertiary Structure:

- The long polypeptide chain of protein molecule undergo folding and refolding on itself and gives rise to a definite three dimensional structure. This is called tertiary structure.
- This structure makes proteins rounded and somewhat rigid molecule.

IV. Quaternary Structure:

- This structure shows the combination of many individual protein subunits each with its own tertiary structure into a complex functional unit.
- Examples are myoglobin (oxygen storage) and hemoglobin (oxygen transport).

Properties of Proteins

- They are complex heavy molecular weight organic compounds.
- They are amphoteric in nature because they contain both acidic (-COOH) and basic (amino) group.
- They react with both acids and bases.
- They can be precipitated from their solution by salts of heavy metals, heat and alcohols etc.
- When proteins are strongly heated or treated with certain reagents they lose their structural organization and their biological functions. This is known as coagulation of proteins.

Importance of Proteins:

- Proteins are the most significant biological compounds of living beings.
- Many of the proteins act as living catalysts called enzymes. These enzymes increase the rate of biological reactions to the extent required by the body.
- The nucleoproteins act as carrier of genetic information or characters. They serve as basis of inheritance of traits.
- Hormones are proteins in nature. They regulate the growth of living organisms and control a number of other physiological functions.
- Some proteins serve as carrier of different substances inside the body. For example hemoglobin (haem containing protein) acts as carrier of oxygen, ceruloplasmin acts as carrier of copper in the blood plasma. Some proteins contribute to the structure of tissues for example collagen, elastin and keratin. Proteins play vital role in the immune system of living organisms.

Enzymes:

- The catalysis of biological reactions is probably the most important task assigned to proteins by nature.
- Hundreds of biological reactions are taking place every minute in different parts of the body for obtaining energy, synthesizing the protoplasmic and other structural materials, digestion, absorption and assimilation of food etc.
- These and so many other biological reactions are catalyzed by certain special proteins known as enzymes.
- The word enzyme was originated from a Greek word "en" means "in" and 'zyme' means yeast after studying the catalytic properties of yeast.
- Enzyme is defined as a complex organic substance which alter the rate of an already initiated biochemical reaction without itself being altered permanently during the reaction.
- Enzymes are soluble, colloidal organic catalysts produced by living cells but they are capable of acting independently of the cells.
- Most of the enzymes are protein in nature and show all the properties of proteins.
- They are precipitated by the usual protein precipitating agents.
- They are non-hydrolysable with nitrogen contents of about 16%. They are de-activated by extreme alteration of pH and high temperature.
- Enzymes are highly specific in nature. It means that an enzyme can work only for one type of reaction in the body.
- The substance upon which an enzyme acts is called substrate of that enzyme.

Role of Enzymes as bio-catalyst:

- Enzymes are playing the decisive role in the digestion of food in different parts of the alimentary canal. For example
- In the Digestion of Carbohydrates
- In the Digestion of Fats
- In the Digestion of proteins

1. In the Digestion of Carbohydrates

- After ingestion food meets saliva.
- Saliva contains an enzyme called salivary amylase or ptyalin. This enzyme catalyses the hydrolysis of carbohydrates of food without affecting proteins and fats.
- In food reaches stomach, the action of amylase comes to an end due to acidic pH of the stomach. When food enters the intestine, pancreatic juice is secreted. This juice contains pancreatic amylase which has the same action as salivary amylase.

In the Digestion of Fats:

There is only slight hydrolysis of fats in the mouth and stomach because no lipase is secreted by the salivary glands while the lipase of the gastric juice is weak and can hydrolyse only small fat molecules.

The lingual lipase enzyme secreted by the Ebner's glands on the dorsum of the tongue remains active in stomach and can hydrolyse or digest about 30% of the ingested fats.

When the fats reaches the intestine, they face pancreatic juice.

This juice contains a pancreatic lipase enzyme also known as steapsin. This enzyme completely hydrolyses or digests all the facts of the food.

But it holds good upto a certain increase in temperature.

- Above that temperature the enzymes undergo denaturation and their activity decreases rapidly.
- On the other hand, decreasing the temperature, the activity of the enzyme is decreased.
- An enzymes becomes less active when cooled and is altogether inactive at 0°C. But their activity can be restored by raising the temperature.
- Enzymes can be stored for years in frozen state.
- The temperature at which an enzyme shows maximum activity is called optimum temperature.
- For most animal enzymes optimum temperature is around body temperature (37°C).
- Some plants enzymes such as amylase has optimum temperature even upto 60°C.

In the Digestion of Proteins:

Digestion of proteins starts in stomach because the saliva contains no enzymes for the digestion of proteins.

The first enzyme that acts upon the proteins of the ingested food is called pepsin present in the gastric juice of stomach. It is best active in acidic pH of 1-2 range.

Pepsin has also milk curdling properties.

When food enters the intestine, pancreatic juice comes into action. This juice contains numerous enzymes for the digestion of proteins.

These enzymes include trypsin, chemotrypsin.

These enzymes are secreted in their inactive forms which are then activated by the action of other enzymes.

For example the inactive trypsinogen is activated to active trypsin by the action of enzyme enterokinase.

Besides, trypsin and chymotrypsin pancreatic juice contains, carboxypeptidase A and B elastase, collagenase etc.

2. pH:

- Some enzymes work in alkaline pH while others in acidic pH
- For every enzyme there is a pH at which it shows the maximum activity. This pH is called optimum pH.
- For example the optimum pH of pepsin is around 2.0 while that of trypsin varies from 8-9 pH.
- There is a pH below which the enzyme loses its activity and at which the enzymes shows the lowest activity.
- This pH is called minimum pH. Most of the enzymes have optimum activities in the range between 5-9.

3. Enzyme inhibition:

- The process by which the activity of an enzyme is decreased or inhibited by the addition of certain substances to the reaction is called enzyme inhibition.
- The different substances which inhibit the activity of enzymes are known as inhibitors.
- There are two major types of enzyme inhibition. These are.
 - a) Irreversible Inhibition
 - b) Reversible Inhibition:

i) Irreversible Inhibition:

- When the inhibitor reacts and form a strong covalent bond with the active site of the enzyme this is termed as irreversible inhibition.
- The inhibitors forms a stable and irreversible complex with the enzyme.
- This complex can not be broken down by physical or chemical methods to restore the active form of the enzyme.

Factors Affecting Enzyme Activity:

number of factors influence the activity of enzymes. Some of these are.

Effect of Temperature

pH

Enzyme inhibition

Effect of Temperature:

Temperature is an important factor in both for enzymatic and non enzymatic reactions.

This is because temperature increases or decreases the kinetic energy and hence changes the number of fruitful collisions among reactants.

Enzymatic reactions, being chemical in nature, their rates increase with increase in temperature.

Reversible Inhibition:

- It is a temporary type of inhibition.
- That is the activity of the inhibited enzyme can be restored or the inactive form of the enzyme can be converted back to the same active form.
- It is sub-divided into.
 - a) **Competitive Inhibition:**
 - The inhibitor competes with the substrate for the active sites of the enzyme.
 - The inhibitor binds to the same active sites of enzymes to which the actual substrate binds.
 - By this way the active sites of the enzyme are blocked and then the substrate is unable to bind to the enzyme.
 - (b) **Non-Competitive Inhibition:**
 - The inhibitor has no structural resemblance with the substrate of the enzyme and, therefore, does not compete with the substrate for the active sites of the enzyme.
 - The inhibitor does not bind to the active sites of enzyme.
 - Inhibitor binds to the site other than active sites of the enzyme therefore, two complexes the enzyme - substrate and enzyme-substrate inhibitor are formed.
 - (c) **Uncompetitive Inhibition:**
 - In this type, the inhibitor does not react directly with the enzyme but it binds to the enzyme substrate complex.

Industrial application of Enzymes

- Enzymes are used in the chemical industry and other industrial applications when extremely specific catalysts are required.
- Useful enzymes are obtained from both plants and animals, but most enzymes are obtained from microorganisms, mainly bacteria and fungi.
 - a) **Biological detergents:**
 - Most of the enzymes for washing come from bacteria adapted to live in hot springs.
 - The enzymes are used for pre-soak condition and direct liquid applications helping removal of protein and starch stains.
 - They are also able to digest fat, oil and grease stains.
 - b) **Fruit Juice production:**
 - During the manufacture of fruit juice the cells of the fruits have to be broken down before the bulk of the juice can be extracted.
 - Plant cell wall is built of cellulose fibres which are held together by pectins and hemicelluloses and they are extremely tough.
 - When very high temperatures are used to break down the fruit-tissues, this will affect

- colour and flavor of the juice. Instead, the fruit is crushed and enzymes preparation containing cellulases and hemicellulases are added.
- These cause cell wall break up and most of the liquid is released.
- c) **Production of Ethanol:**
 - In Biofuel industry, cellulase are used to break down cellulose into sugar and which can then be fermented to produce ethanol.
- d) **High Fructose syrup:**
 - A sweetener that is widely used in food and drinks is high fructose corn syrup.
 - It is manufactured from starch in corn fruit.
 - The grains are milled to a starch slurry and the enzyme amylase is added.
 - Finally the syrup is passed down a column of immobilized glucose isomerase enzymes. This converts much of glucose to fructose.
 - It is added to sweeten foods without adding too many calories.
- e) **Paper Industry:**
 - In paper industry enzymes like amylases, xylanases, cellulases and ligninase are used.
 - Amylase degrade starch to lower viscosity, aiding sizing and coating of paper. Xylanases produce bleach required for decolourizing.
 - Cellulases smoothen fibers, enhance water drainage and promote ink removal.
 - Lipases reduce pitch and lignin degrading enzymes remove lignin to soften paper.

Lipids

- Lipids are a heterogeneous class of organic compounds.
- They are greasy substances which are relatively insoluble in water but considerably soluble in organic solvents like ether, chloroform benzene etc.
- Lipids perform several important functions in living organisms.
- They act as storehouses of metabolic energy, as structural components of membranes, as protective and insulating coatings
- Nervous tissues are rich in lipids where they play important role in their functions.
- The subcutaneous fat serves the role of insulating against atmospheric heat and cold.
- Lipids may be saponifiable or unsaponifiable.
- Fats, oils and waxes are saponifiable while terpenes and steroids are unsaponifiable lipids.

Classification of Lipids

Lipids have been classified into the following three major classes.

- Simple Lipids
- Derived lipids
- Derived lipids

1. Simple Lipids:

- These are the esters of fatty acids with different types of alcohols. These include:
 - a) **Fats and Oils:**
 - These are the esters of fatty acids with trihydroxy alcohol called glycerol
 - Fat is solid at room temperature while oil is liquid at room temperature.
 - Oils contain more unsaturation in the alkyl part of fatty acids than fats.
 - These are also known as triglycerides or triacylglycerols.
 - Fatty acids are long chain carboxylic acids containing usually 12-18 carbon atoms per molecule.
 - ii. **Waxes:**
 - These are the esters of fatty acids with high molecular weight monohydroxy alcohols.
 - For example bee wax, carnauba wax etc

2. Compound Lipids:

- These are the esters of fatty acids with alcohols containing some additional groups, as well.
- They are further divided into
 - i) **Phospholipids:**
 - These lipids contain fatty acids, phosphoric acid, nitrogenous bases along with some other constituents.
 - They are also called phosphatide.
 - ii) **Glycolipids:**
 - They contain fatty acid, alcohol and carbohydrate.
 - They are present in large amount in the white matter of the brain and in the myelin sheaths of nerves.
 - iii) **Sulpholipids:**
 - They contain a sulphate group in addition to fatty acids, alcohol and carbohydrate.
 - iv. **Lipoproteins:**
 - These are the complexes of lipids with proteins.

3. Derived Lipids:

- These are the substances derived by the hydrolysis of simple and compound lipids.
- These include fatty acids, alcohols, mono and triglycerides, steroids, terpenes and arthenoids.

Structure:

- Lipid has no common structure.
- The most common occurring lipids are triglycerides and phospholipids.

- Triglycerides are fats and oils.
- Triglycerides have a glycerol backbone bonded to three fatty acids.
- If the three fatty acids are similar, the fats are called simple triglycerides.
- If the fatty acids are not similar, they are known as mixed triglycerides.
- The second most common lipids are phospholipids.
- They are found in cell membrane of animals and plants.
- Phospholipids contain glycerol and fatty acids as well as phosphoric acid and low molecular weight alcohol.
- Some lipids are as follow:
 - Stearic acid
 - Oleic acid
 - Wax
 - Phospholipids
 - Cholesterol
 - B-Carotene

Physical Properties:

- Natural fats are colourless, odourless and tasteless.
- They are insoluble in water but are highly soluble in organic solvents like benzene, ether, chloroform etc.
- They have well defined melting and solidifying points.
- They have low specific gravity and, therefore, float on the surface of water.

Chemical Properties:

- Hydrolysis
- Addition reactions
- Oxidation
- Rancidification

1) Hydrolysis:

- Natural fats undergo hydrolysis with acids or bases in boiling water where they produce free acids and glycerol.
- In case of base hydrolysis, the base reacts with free fatty acids and produce salts of fatty acids called soaps.
- This process is called saponification
- $\text{Fat} + \text{NaOH} \rightarrow \text{soap} + \text{Glycerol}$

2) Addition Reactions:

- Unsaturated fatty acids of fats and oils undergo addition reactions at the points of unsaturation and produce addition products.
- The oils which contain more unsaturation are hydrogenated to produce solid ghee.
- By this way inedible and cheap oils such as cotton seed oils are hydrogenated and converted to solid and edible ghee.

3) Oxidation:

- Fats rich in unsaturated fatty acids (linseed oil) undergo spontaneous oxidation at their double bonds and produce aldehydes, ketones and resins.
- They form a thin transparent coating on the surface to which the oil is applied.
- These are known as drying oils. They are used in manufacture of paints and varnishes.

4) Rancidification:

- Natural and specially animal fats contains lipase enzyme.
- By the action of atmospheric oxygen, in the presence of lipase the fats undergo partial hydrolysis and oxidation at their double bonds. This produces volatile carboxylic acids of sour taste and unpleasant smell. This process is called rancidification and the fat is said to have become rancid.
- $\text{Tristearian} + \text{H}_2\text{O} \rightarrow \text{Stearic Acid} + \text{Distearian}$

Science

- Insulin is peptide hormone secreted by the Beta cell of pancreatic islets of Langerhans and maintain blood glucose level by facilitating cellular glucose uptake, regulating carbohydrate and lipid and protein metabolism.
- Diabetes mellitus is the group of metabolic disease in which patient has high blood sugar level which is either due to the fact that pancreas does not produce enough insulin or cells do not respond to the insulin that is produced.
- Cholesterol is the precursor of five major classes of steroid hormones,
 - Progesterone
 - Glucocorticoids
 - Mineralocorticoids
 - Androgen
 - Estrogen.
- These hormones are powerful signal molecules.
- With amino acid derivatives hormones are commonly derived from tyrosine and tryptophan

- The tyrosine derived hormones are thyroid hormones and catecholamines.

Nutritional and Biological Importance of Lipids:

- Lipids perform a number of different functions in living organisms. Some of these are listed below.
- Lipids provide food which is highly rich in calorific value:
 - One gram of lipid on complete oxidation produces 9.3 kcal of heat which is about double the amount produced by carbohydrates and proteins.
- Lipids are insoluble in water and, therefore, they can be stored easily in the body as food reserves.
- These food reserve are then used by the organisms during hibernation periods.
- Lipids in association with different proteins form the important constituents of cell membranes.
- Fats have high insulating capacity.
- Great quantities of fats are deposited in the subcutaneous layers in aquatic mammals such as whale and in animals of cold climates.
- These fat deposits protect these animals from severe cold and severe temperature changes.
- Some lipids specially phospholipids play a key role in the absorption and transportation of fatty acids in the body.
- Sex hormones, adrenocorticoids, cholic acids are synthesized from a steroid lipid known as cholesterol.
- Lipids serve as carrier of fat soluble vitamins such as vitamin A, D and E in the body.
- Squalene, a steroid present in the blood of shark has antibiotic and antifungal properties. This explains why sharks rarely contract infections and almost never get cancer..

Nucleic Acids:

- Friedrich Miescher a 25 year old Swiss chemist isolated nuclei from pus cells (white blood corpuscles).
- He found that these nuclei contained an unknown phosphate rich substance. He named it as nuclein. This newly discovered substance was quite different in properties from carbohydrates, proteins and fats. He also isolated a nucleoprotein complex from ripe salmon sperm. It was a basic protein which he named protamine.
- It was Altmann who for the first time used the word nucleic acid in 1889. He also discovered the existence of two different types of nucleic acids namely DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).
- Later on Watson and Crick determined the structure of nucleic acids.

- They are present in every living organism as well as in viruses.
- They have been found to be the essential substance of the genes and the apparatus by which the genes act or express themselves.
- They contain in their structure the blueprints for the normal growth and development of each and every organism.
- They are responsible for storing, expressing and transmitting genetic information and mutation in living organisms.

Types of Nucleic Acids:

There are two different types of nucleic acids.

- DNA (deoxyribonucleic acid) it is present in nuclei and in some viruses. It is the main constituent of chromosome.
- RNA (Ribonucleic acid) is present in the cytoplasm and in some Viruses.

Structural Components of DNA and RNA:

- Both DNA and RNA are formed by the polymerization of large number of units known as nucleotides.
- That is why DNA and RNA are polynucleotides.
- A nucleotide is composed of a
 - nitrogenous base
 - a sugar
 - a phosphate group.
- DNA differs from RNA in the type of nitrogenous base and type of sugar unit.
- The nitrogenous bases are of two types
 - Purine
 - pyrimidine
- There are two different types of purine derivatives. These are
 - Adenine
 - Guanine
- Similarly there are three derivatives of pyrimidine. These are
 - Cytosine
 - Thymine
 - Uracil
- DNA and RNA contain two different types of sugars. One is deoxyribose and the other is ribose sugar. Both these sugars are in cyclic furanose form.

Difference between DNA and RNA

- The DNA differs from RNA in the sense that the pyrimidine bases of DNA are cytosine and

thymine while the pyrimidine bases of RNA are cytosine and uracil.

- On the other hand both DNA and RNA contain the same types of purine bases called adenine and guanine.
- The pentose sugar of DNA is deoxyribose while that of RNA is ribose.
- DNA is a double stranded molecule while RNA is a single stranded molecule.
- DNA is mainly present in the nucleus while RNA is mainly present in the cytoplasm of the cells.

- Both DNA and RNA are polynucleotide molecules.
- A nucleotide is formed by the combination of nitrogenous base (Purine and Pyrimidine), ribose sugar (ribose or deoxyribose) and phosphoric acid.
- Nucleotide = Nitrogenous Base + Sugar + Phosphoric acid.
- DNA is made up of repeating units of deoxyribonucleotides while RNA is a polynucleotide.
- A DNA molecule is formed by two antiparallel long polydeoxyribonucleotide chains which wind on each other. These two chains are held together throughout the whole length by hydrogen bondings present between the nitrogenous bases.
- Adenine joins only to thymine while guanine joins only to cytosine.
- Adenine joins to thymine by two while cytosine joins to guanine by three hydrogen bondings.
- This pairing of bases is highly specific.
- Adenine will never join cytosine and guanine never joins thymine

Nucleic Acid Polymers

- Monomer means one unit, while polymer means many units.
- In chemistry many compounds are polymers (large molecules) that consist of repeating, identical or very similar units.
- Nucleic acid polymers are DNA or RNA.
- The polymer DNA has deoxyribonucleotides as its monomer. While polymer RNA has ribonucleotides as its monomers.

Storage of Genetic Information:

- DNA is the ultimate carrier of heredity in all the living organisms
- Genes are composed of DNA which contains genetic information in the form of codes.

- A sequence of three nitrogenous bases on DNA strands contains code for one amino acid synthesis of proteins which occurs inside ribosomes present in the cytoplasm of living cells.
- The information stored in the form of genes which are parts of DNA are transmitted to the cytoplasm in the form of messenger RNA or mRNA. There is another type of RNA called transfer RNA (tRNA) which reads out the message of mRNA and brings the amino acids to the ribosome in the form of amino acid tRNA complexes.
- Then these amino acids are incorporated into the peptide chain. This process is called translation.

Minerals of Biological Significance

- Minerals essential for life are the inorganic nutrients, which are needed by living organism for vital functions but cannot be synthesized by them.
- They are naturally present in the soil and river water.
- Plants take up minerals from the soil.
- Animals get their minerals in drinking water and eating plants as food.
- We receive these inorganic substances from both animals and plants in our diet. Sometimes drinking water also supplies appreciable quantity of minerals.
- Purified salts such as NaCl is used in food preparation is also good source of minerals for human consumption.
- Minerals are mainly classified as macronutrients (calcium, phosphorus, magnesium and sulphur etc) and micronutrients (Iron, zinc, iodine, copper and manganese)

Biological significance of Iron, Calcium, Phosphorus and Zinc

a) Iron:

- Iron is one of the important element because it is a part of haemoglobin, a carrier of oxygen in the body.
- An adult man requires about 10mg of iron in his daily diet.
- Growing children, pregnant and lactating women require greater concentrations of iron due to the loss of blood in menstruation.
- Sources of iron :
 - Liver
 - Heart
 - Kidney
 - egg yolk
 - green leafy vegetables

- wheat
- The daily synthesis of haemoglobin, requires about 27mg of iron but the same quantity of iron is liberated by the break down of body haemoglobin, therefore, only a small quantity of iron is required unless there is a loss of blood from the body.
- About 300 mg of iron is transferred to the fetus in uterus. Since there is no loss by excretion, therefore, this amount is sufficient during uterine life.
- Deficiency of iron produces a disease called anemia. This may be due to the lack of iron in the diet or a deficiency in its absorption by the body.
- Excess of iron is stored in the form of hemosiderin in the skin, pancreas, liver, spleen etc. This leads to bronzed appearance of the skin, diabetes mellitus and cirrhosis. This state is called hemochromatosis or hemosiderosis.

b) Calcium:

- Calcium is present in largest quantity on account of being the main constituent of bones and teeth.
- About 1 kg of calcium is present in man 99% of which is present in bones in the form of hydroxyapatite crystals
- Small amount of calcium is also present in blood.
- The main sources of calcium are
 - Milk
 - milk products
 - egg yolk
 - legumes
 - nuts
 - green leafy vegetables
- Calcium is required for the regulation of a large number of cellular activities, muscle and nerve functions, hormonal action, blood coagulation and cell motility.
- Increase in the concentration of calcium in plasma leads to a condition known as hyperparathyroidism.
- Decrease in plasma calcium level leads to a condition known as hypocalcaemia.

c) Phosphorous:

- Phosphorous is also the major constituent of bones and teeth.
- It is present in all the body cells in association with proteins, lipids and carbohydrates in the form of phosphoproteins, phospholipids and similar compounds.
- It has a unique role in the storage and transformation of energy in the body.
- An adult requires about 800mg per day of phosphorous.
- It is present in association with calcium in its sources.

- Proteins of food also provide good amount of phosphorous to the body.
- An increase in the plasma phosphate level due a decrease in its excretion leads to kidney dysfunction. But a decrease in the plasma phosphate level due to an increase in its excretion leads to renal rickets.

d) Zinc:

- Zinc is an important element for the normal growth, reproduction and longevity of animals.
- It is a constituent of several types of enzymes such as alkaline phosphatase, carbonic anhydrase etc.
- It also forms a complex with insulin and helps in its storage and release according to the need of the body.
- It is also required for maintaining the plasma concentration of vitamin A.
- The different sources of zinc include
 - Meat
 - Liver
 - Eggs
 - Fish
 - milk
 - cereals
- Deficiency of zinc results in delayed wound healing and impairment of acuity of taste.

MIX

- Biochemistry studies the chemistry of life.
- Carbohydrates, proteins, lipids, nucleic acids and enzymes are called biomolecules.
- Carbohydrates are organic compounds of carbon, hydrogen and oxygen.
- The formula of carbohydrate is $C_n(H_2O)_n$.
- Carbohydrates are classified as
 - Monosaccharides
 - Disaccharides

- Polysaccharides

- Glucose is known as "aldose" and has aldehyde structure at carbon atom no.1.
- Fructose is known as ketose and has a "keto" structure at carbon atom no.2.
- Monosaccharides and oligosaccharides are collectively called sugars.
- Polysaccharides are known as non-sugars.
- When two monosaccharides units combine. Their linkage is called glycosidic linkage or glycoside bond.
- Amino acids are monomers of proteins and they are connected by peptide bond.
- The structure of proteins are considered at four levels
 - Primary
 - Secondary
 - Tertiary
 - Quaternary
- Lipids are heterogeneous class of organic compounds.
- Lipids may be
 - Saponifiable
 - Non-saponifiable
- The oils which contain more unsaturation are hydrogenated to produce solid ghee.
- DNA and RNA are two examples of nucleic acids and their function is
 - Replication
 - Protein synthesis
- Enzyme are protein in nature which speed up a chemical reaction.
- Enzyme inhibition may be
 - Reversible
 - Irreversible
- Minerals essential for life are the inorganic nutrients that are needed by the living organism. For vital function, but cannot be synthesized by them.

Chap No. 22 INDUSTRIAL CHEMISTRY**Industrial chemistry**

- Industrial chemistry is concerned with chemical processing of raw materials to useable and profitable products.
- Chemical processing may be defined as the industrial processing of the chemical raw materials leading to the products of enhanced industrial value.
- Generally this involve the chemical conversion, as in manufacture of sulphuric Acid from sulphur by

oxidation and hydration, but the production of fibers from chemicals is also included such as nylon from hexamethylene diamine and adipic acid by more complicated chemical reactions.

Economy of Pakistan

Chemical sector plays a fundamental role in economic development any nation.

- The globalization forms the structure of the modern world.
- Chemical industry also produces fibers and dyes which are used in textile industry and supply synthetic sweeteners and synthetic flavours which are used by food manufacturing companies.
- The provision of essential chemicals to the pharmaceutical industry and health care industry is also a major role of chemical industry.
- Artificial rubber requirement of Pakistan industry are also met by the very same chemical industry.
- Chemical industry contributes indirectly to almost every sector of economy.

SAFETY CONSIDERATION IN THE PROCESS OF INDUSTRY

- The following safety consideration in the process of industry must be kept in view before launching any industrial activity
- To keep away the factory itself from corroding away, proper material of construction should be selected by the designing chemical engineers.
- To avoid harmful impurities in raw materials, to follow the course of chemical reactions and to secure the requisite yield and purity of products, careful process control by periodic analysis is required as well as modern instrumentation and automatic control.
- To transmit goods in a clean and economical manner from the manufacturer to the customer, suitable containers must be provided
- To affect the safety of workmen and the plant all procedures, must be carried on in a non-hazardous manner.
- To secure the processes from excessive competition and to ensure an adequate return for a large sums spent on the research and
- To guarantee progress to continue profits and to replace obsolescent processes and equipment much attention and money must be spent upon continuing research and development
- To prevent the contamination of water and air, factories must avoid discharge of toxic material into the air and water of their localities.

Dyes

- A dye is a substance which adds value to products for their cost.
- In most of the cases the colour of a product is the reason for its sale.
- The purpose of a dye is usually to help the purchaser sell his product to his customer.
- A dye must be coloured, but it must also be able to impart colour to something else on a reasonably

permanent base before it can be considered as a dye.

- Chemical Composition of a dye:
- A dye consists of a colour producing structure called "The chromogen" (electron acceptor) and a part to regulate the solubility and dyeing properties called the auxochrome (electron donor). Without both parts, the material is simply a coloured body
- The chromogen is an aromatic body containing a colour giving group, commonly called the "chromophore".
- Chromophores groups cause colour by altering absorption bands in the visible spectrum.
- Some common chromospheres are given in the table

S.No	Chrophore	Structure
1	Nitroso group	NOO or =N-OH
2	Nitro group	NO ₂ or NOOH
3	Azo group	-N=N-
4	Ethylene group	-C=C-
5	Carbonyl group	-CO-
6	Carbon nitrogen group	-CN-
7	Carbon Sulphur Group	CH ₃ -SH

- Dyes are usually classified on the basis of chromophore groups.
- The auxochrome, the part of the dye which causes it to adhere to the material which it colours (usually textiles) are -NH-OH, -NR-COOH and -SO₃H of these groups. -NH₂ and -NR₂ cause solubility in acids while -OH-COOH and SO₃H cause solubility in basic solutions.

Classification of Dyes:

- Dyes are of many types. They may be classified into the following classes. The basis of classification being the use or "application of the dye"

1. Acid dyes:

- They are used for dyeing protein fibers such as wool, silk, nylon; also leather and paper.
- They contain one or more sulfuric acid substituents or other acidic groups.
- An example of the class is acid yellow 36 (Metanil yellow).

2. Basic Dyes:

- These dyes can be used to dye wool or cotton with a mordant but are usually used for duplicator inks, carbon paper and typewriter ribbons.
- Insolvents other than water, they form writing and printing inks.
- Basic dyes are mostly amino compounds soluble in acids and made insoluble by the solution being made basic.
- Basic dyes were the first dye class made synthetically; "mauve" was a basic dye.
- Examples of the basic dyes are basic brown 1 (bismark brown), basic violet 3 (crystal violet) etc.

3. Azo dyes:

- These are brilliant and long-lasting dyes and are used primarily for printing on cotton.
- These "ice colours" are made right on the fiber by coupling-diazotized materials while in contact with the fibers.

4. Direct dyes:

- These are used to dye cotton directly i.e. without the addition of a mordant.
- They are also used to dye union goods (mixed cotton and wool or silk).
- These are generally azo dyes and their solubility in the dyes bath is often reduced by adding salt.
- Direct orange 26 and direct black 22 are typical direct dyes.

5. Disperse dyes:

- Some fibers such as plastics, cellulose acetate, polyesters, nylon fibers are difficult to dye.
- Disperse dyes are applied as very finely divided materials which are absorbed on to these fibers with which they then form a solid solution.
- The dye dissolves into the fiber at or near the glass transition temperature of the polymer.
- Some typical examples of the disperse dyes are disperse red 4, disperse red 77, disperse orange 25, disperse blue 27 etc.

6. Fiber-reactive dyes:

- These dyes react with the substrate, usually cellulose to form a covalent link (bond) between the dye and the fiber.
- Cotton, rayon and some nylons are dyed by these dyes.
- Examples of this type include vinyl sulfone (sulfate ethyl sulfone)

7. Mordant dyes (and lakes):

- Some dyes combine with metallic salts to form highly insoluble coloured materials, called lakes.

- Lakes are usually used as pigments.
- If a cloth made of cotton, wool or other protein fiber is impregnated with an Al, Cr or Fe salt and then contacted with a lake forming dye, the metallic precipitate forms in the fiber and the colours become far more resistant to light and washing.
- The azo and anthraquinone nuclei, having attached the groups like -OH and -COOH, can act as mordant dyes.

8. Sulphur dyes (sulphide dyes)

- These dyes have been used for a long time.
- They are large low costing group of dyes which produce dull shades on cotton.
- The chromophore is complex and not well defined. Sulphur dyes are usually colourless when in the reduced form in a sodium sulfide bath but gain colour on oxidation.

9. Solvent dyes:

- Solvent dyes, sometimes called the spirit-soluble dyes are usually azo, methylmethane or anthraquinones.
- They are used to colour oil, waxes Varnishes, shoe polishes and gasolines.

10. Vat -dyes:

- Vat-dyes are water insoluble organic pigments that become water soluble when mixed with powerful reducing agents in the dyeing process.
- The reducing operation formerly was carried in wooden vats and hence they name vat -dyes.
- These have highly complex chemical structures and mostly are derivatives of anthraquinone or indanthrone.
- Vat -dyes are quite expensive and are most often used on cotton fabrics that are to be subjected to severe conditions of washing and bleaching, such as men's shirts.
- Some vats are supplied as pastes for printing.
- The best known dyes of this class is indigo, which is one of the most popular colours in the world.

Pesticides:

- The use of chemical pesticides has been a major feature of modern agriculture.
- Our modern system of agriculture depends not only on our ability to stimulate plant growth, but also on our ability to control various insects or more generally, "pests" that would eat or destroy the crops in the fields or the harvest in the storage sheds.

- It is not difficult to kill all the troublesome creatures that we include as pests.
- Poisons such as lead arsenate, Pb (Aso), have been in use for a long time. Both lead and arsenic are damaging to a wide variety of living systems.
- Another traditional insecticide is nicotine sulphate, which is obtained from plants but is extremely poisonous to most pests and to man.
- Pesticides such as these general poisons are not really satisfactory.
- We would prefer a substance that destroys specific pests without injuring other insects, wild life, or man.
- Secondly a pesticide that breaks down in nature into harmless products is preferred.
- Modern insecticides were ushered in by DDT in 1943.
- Its remarkable effectiveness against mosquitoes, which carry malaria and lice was immediately demonstrated in the world war II campaigns in Italy and the Pacific. DDT has the formula.. and the name "dichlorodiphenyltrichloroethane".
- It is good in specificity in acts directly on insects and not on mammals. But it does not like bees, that assist them distinguish between bad insects that destroy our crops and good insects,
- Unfortunately DDT fails to meet the second criterion ie it does not daily break down in nature to give harmless substances.
- DDT is a very stable chemical. Its half life is estimated to be 10-15 years.
- It means that half of any DDT applied in any year still exists, somewhere, 10 or 15 years later.
- The persistence of DDT is more troublesome by its tendency to become concentrated in all forms of animal life. (The process is some times referred to as biological magnification). As is clear from its structure,
- DDT can not become involved in hydrogen bonding to water molecules, so it is water-insoluble. Further more the DDT molecule is non polar.
- If a sample of DDT is shaken up with a two layer oil -and-water system, almost all the DDT will be found in the oil layer.
- In nature its distribution occurs and DDT accumulates in animals and in particular in their fatty tissues. Thus, although DDT can be used in very small quantities to control insects, it accumulates in the fatty tissues of each successive member of the food chain. An area may be sprayed with DDT so that the concentration of the DDT in the waters of the area might be much less than 1 ppm.
- But the food chain that proceeds from insects through fish to fish-eating birds can concentrate the DDT until it is at the 100 or 1000 ppm level.
- Even man is not immune from this DDT accumulation and our fatty tissues now contain something over 10 ppm of DDT more than would be tolerated in the foods we eat.
- Generally, it has been found that almost all chlorinated pesticides including DDT appear to have a variety of undesirable effects. That is why pressure from environmentalists has lead to the nearly total ban of the use of DDT in the US and all over the world.
- However, there are some chlorinated pesticides that are used for more specific target was DDT. They include mirex, chlordane, heptachlor, aldrin and dieldrin
- The controversy over DDT and other chlorinated hydrocarbons so attempts to find pesticides of a different chemical type.
- One of the important alternatives is parathion.
- Parathion: This compound breaks down fairly readily to products that appear to cause no biological damage. It is, however, toxic to man and other animals as well as to insects. Thus it avoids long term damage but unless handled carefully it can make for that by short term effects.
- In short, the ideal pesticide is clearly not yet available.
- In fact, chemical poisons will probably turn out to be only one route to the control of the pests that compete with us for our crops.
- Petrochemicals:
- The first organic chemical made on large scale from a petroleum base was isopropyl alcohol (isopropanol), first produced by Standard Oil of New Jersey in 1920. By 1925 Standard Oil of New Jersey was making 75 tons per year of isopropyl alcohol and the emergence of petrochemical industry was established in many minds.
- Currently well over 80 per cent of all organic chemicals are petrochemicals.
- While separating individual species from petroleum, the processes involve well refined engineering methods.
- The most important of these methods are
 - i) distillation
 - ii) selective adsorption.
- Alkylations involving propenes and butenes yield C_6 to C_8 Hydrocarbons for high octane gasoline.
- Propylene becomes poly propylene, polyamines or propylene glycol and others.
- Likewise 98 percent of the raw material, for aromatic compounds, is obtained from petroleum.
- The most basic raw materials (table 22.2) supplied by petroleum.
- Fractional Distillation of Petroleum:
- Petroleum in the unrefined form is called crude oil.

- It is a naturally occurring thick viscous brown or greenish black liquid which is obtained from earth crust.
- It consists of mostly hydrocarbons along with some other elements, mainly sulphur, nitrogen and oxygen.
- Crude oil is first treated to remove sulphur or sulphur compounds that may be present. The cleaned hydrocarbon material is then distilled, and fractions with various boiling ranges are collected.

The principal fractions and some of the principal routes in the treatment of crude oil in an oil refinery during fractional distillation are:

1. Refinery gas:

- It is a mixture of hydrocarbons contain methane, ethane, propane, and butane, ie, to atoms molecule.
- It is obtained at a temperature below 20°C , and is used as "fuel" and for making other organic compounds.

2. Petroleum ether: It is obtained in the boiling range

- $20^{\circ}\text{--}60^{\circ}\text{C}$, contains pentane and hexane (-) and is used as solvent.

3. Light naphtha:

- It is obtained in the boiling range $60\text{--}100^{\circ}\text{C}$. contains hexane and heptane ($\text{C}_6\text{--}\text{C}_7$)
- It is used as solvent

4. Gasoline:

- This is the most important fraction containing hydrocarbons from C_7 to C_{10}
- It is obtained in the boiling range $80\text{--}180^{\circ}\text{C}$ and is used as motor fuel.

5. Kerosine (Paraffin oil):

- It is obtained in the boiling range $160^{\circ}\text{--}300^{\circ}\text{C}$ and contains hydrocarbons from C_{11} to C_{15}
- It is used as jet fuel, and for oil-fired domestic heating.
- It can also be used for cracking to produce gasoline (motor fuel).

6 Heavy oil (Diesel oil, fuel, oil, gas oil):

- This fraction is obtained in the boiling range 300° to 400°C and contains hydrocarbon from C_{15} to C_{18}
- It is used as industrial fuel and as fuel for diesel engines.

7. Lubricating oil:

- It is a mixture of non-volatile liquids which is obtained at a temperature above 400°C .
- It contains hydrocarbons from $\text{C}_{18}\text{--}\text{C}_{20}$
- It is used for lubricating heavy machinery
- The final residue (with more than C_{30}) is a black coal tar and is called asphalt, pitch or bitumen.
- It is used for metalling roads

Synthetic polymers (PVC and Nylon)

- A polymer is a macromolecule (sometimes with a very high molecular weight) formed as a result of a process known as polymerization whereby small organic molecules combine together to form large molecules (polymers).
- The small molecules which under go polymerization are called "the monomers."
- Thus a polymer is a large molecule built up from man hundreds or thousands of monomer units joined together.
- The well known plastic polyethylene or polythene is composed of large molecules formed by the repeated combination of ethene molecules.
- Polymers are classified as either "addition polymers" or "condensation, polymers" depending on their method of formation.

Addition Polymers:

- In these polymers, the repeating unit (monomer) keeps on adding to itself or to the growing polymer so that a long chain polymer is produced. That is to say addition polymer results from the self-combination of many monomer units into a substance with a molecular weight which is a multiple of the monomer.
- The empirical formula of the addition polymer is the same as that of the monomer. For example, when ethylene is heated
- Addition polymers are
 - Polyethylene
 - Polyvinyl chloride)

Industrial Preparation of PVC:

- A typical recipe lists 100 parts of water, 100 parts of liquid vinyl chloride, 1 part of a persulfate catalyst and 1.5 parts of an emulsifier such as sodium lauryl sulphate.

- The autoclave operates at approximately 50°C for 72 hours to give a yield of 90 percent of polymer with a particle size of 0.1 to 1.0m
- Recovery of these particles may be accompanied by spraying or by coagulation by acid addition.
- A PVC compound can be tailor-made to achieve whatever balance of properties is desired by using plasticizers, stabilizers, lubricants and fillers.

Condensation Polymers:

- In the chemistry of carbon there are many reactions where the combination of two or more substances is accompanied by the elimination of small simple molecules such as water, hydrogen chloride (HCl), ammonia (NH₃) or methanol (CH₃OH). Such reactions are often called condensation reactions.
- If the carbon-chain backbone has two functional groups attached to it, a condensation reaction can occur involving polymerization.
- The polymer produced in such a case is called condensation polymer.
- For example, Nylon is a condensation polymer, produced by the reaction between a diamine and a dibasic organic carboxylic acid.
- If the diamine is hexamethylenediamine (1,6-diaminohexane) and the dibasic acid is adipic acid (hexanedioic acid) then the condensation polymer is nylon (6, 6) (six carbon atom in each monomer).
- Preparation of Nylon (6, 10) (the nylon rope trick)
- 50 cm of a 2% (by volume) solution of decanedioyl dichloride (sebacoyl chloride) in CCl₄ is measured into a 100 cm tall-form beaker 25 cm of an aqueous solution containing 2.2g of 1,6-diamino hexane (hexamethylene diamine) is added carefully to the beaker so that the aqueous solution floats on top of the CCl₄ solution, without mixing.
- A thread of the nylon is drawn from the interface between the two liquids, using a pair of forceps and wound around thick glass rod. (Figure 22.2).
- Uses of PVC and Nylon
- PVC or poly vinyl chloride is widely used in imitation leathers floor coverings, corrugated roofing material, drainage pipes electrical pipes, gramophone records etc.
- Nylon is well known as synthetic fiber in carpets, fabrics, rope stockings and other clothings. Because of its mechanical strength, nylon is also used in moulded machine parts such as gears and bearings.

COSMETICS

a) Lipstick

- Lipsticks in their modern form were introduced after world war I
- Lipstick is the cosmetic which is generally formulated to provide both protection (for the delicate tissues of the lips) and colour (for appearance)
- They are made to be neutral in taste, stable under normal fluctuation of temperature, moisture and air flow and lacking major toxicity and irritancy
- The chemical composition of lipsticks varies greatly.
- It may include a mixture of oils, waxes, pigments, antioxidants and preservatives.
- Usually perfumes are also added in minute quantity to combat the unpleasant fatty odour of the oil.
- Lipstick is mainly composed of a mixture of non-volatile oil (e.g. castor, vegetable, mineral or wool fat, lanolin oil) and solid wax (e.g. bees wax or carnauba).
- The addition of oil makes the wax-based product to be softened and easily applied.
- To reduce the "stickiness", usually, esters of fatty acids (like 2-propyl myristate) is also added.
- The most important characteristic of a lipstick is considered to be its colouration.
- The colours and dyes of lipsticks include many water-soluble (also fat soluble) products, such as erythrosine (redish pink synthetic dye), amaranth (dark red to purple azo dye), brilliant blue eosin or tetrabromo fluorescein.
- The dyes must be water-insoluble, otherwise, the colour would quickly fade or be removed in a short time by the consumer through the movement of the saliva-soaked tongue across the lips. Water-soluble dyes such as green or blue food dyes can be used to provide lipstick colouration, but they are, usually, first combined with metal oxides such as aluminum hydroxide (Al(OH)₃) to form an insoluble precipitate that is then suspended in the oil base of the lipstick.

b) Nail Varnish

- Nail varnish or Nail Polish is a lacquer applied to human finger nails or toe nails to decorate or protect the nail plate.
- Nail polish started traditionally in clear red, pink and brown colour
- Since that time, many new colours and techniques have been developed, resulting in nail polish that is found in an extremely diverse variety of colours.
- Beyond solid colours, nail polish has also developed an array of other designs and colours. Such as nail polish stamps, crackled, magnetic nail polish strips and stickers.

- Some nail polishes are used to cause nail growth, make nails stronger, prevent nails from breaking, cracking and components in manicure litting and to stop nail biting. Nail polish may be applied as one of several
- Most of nail polishes are made up of nitrocellulose dissolved in a solvent (e.g; butyl acetate or ethyl acetate) and either left clear or coloured with various pigments.
- Basic components included are: film forming agents, resins and plasticizers, solvents and colouring agents.
- Adhesive polymers (e.g; tosylamide-formaldehyde resin) are added to make sure that the nitrocellulose adheres to the nail surface.
- Plasticizers (e.g; camphor) or chemicals that link between polymer chains, spacing them to make the film sufficiently flexible after drying. Pigments and sparkling particles (e.g; mica) add desired colour and reflecting properties
- Thickening agents (e.g; stearalkonium hectorite) are added to maintain the sparkling particles in suspension within the bottle. Ultraviolet stabilizers (e.g; benzophenone-I) resist colour changes when the dry film is exposed to direct sunlight.
- Nail polish ingredients often include toluene, formalin etc. Solvents such as toluene and xylene and petroleum based products have been linked to cancer. Formaldehyde (formalin) may cause allergic reactions and is unsafe for use by asthmatic people. It is a carcinogen.
- However, the nail polish industries (makers) are under pressure and are now trying to reduce or eliminate toxic ingredients, including phthalates, toluene and formaldehyde.
- Water based nail polish is based on acrylic polymer emulsion (e.g; Styrene-acrylate copolymer) and pigments similar to those used in water colour paints.
- This is marketed as environmentally conscious products since nail polish is considered a hazardous waste by some regulatory authorities. When applied, the solvent (water) does not completely evaporate as in the case of the traditional nail polish; part of water is absorbed through the fingernail.

c) Nail Polish Remover

- Nail polish is removed with nail polish remover or nail pads which is an organic solvent, but may also include oils, scents and colouring.
- The most common type of nail polish remover contains acetone dimethyl ketone,
- It is powerful and effective but is harsh on skin and nails which can even make them more brittle.

- Acetone is a volatile organic compound which can also be used to remove artificial nails, that are usually made of acrylic.
- There are many different types of nail polish removers in the market and different brands may have different chemical compositions.
- However, the principal ingredients in most of them are acetone, ethyl acetate or butyl acetate and alcohol.
- The "non-acetone nail polish remover" usually contains ethyl acetate which is less aggressive solvent and can therefore, be used to remove nail polish from artificial nails.
- These chemicals used are known to dehydrate the skin, cause irritation to eyes and make nails dry and brittle.
- They also have a distinct chemical smell and are highly inflammable.
- To counter the dehydration and brittleness effects, many removers also contain conditioning ingredients like castor oil, ethyl palmitate or lanolin.

Application:

- With liquid removers, the remover is taken on a cotton ball or tissue and wiped over the nail to strip away the finger nail polish on it.
- Depending upon the type of finger nail polish, the number of applied coats and the type of remover, one application may suffice for removal or several application may be necessary.
- To understand how nail polish remover works, it is necessary to know that a finger nail polish remover and a finger nail polish both contain similar organic solvents; the nail polish also contains drying agents, thickeners, hardening agents and colouring agents.
- The organic solvent in a nail polish keeps them in a liquid state, while the solvent present in a remover, dissolve the hardened polish and transforms it back into its original liquid form.
- When the nail polish remover is applied to the nail polish that is to be removed, the solvent molecules of the remover interrupt, loosen and break the polymer chains of the polish.
- This dissolves the hardened polish and transforms it back into its original liquid form.
- It can then be wiped off from the nail.

d) Hair Dyes

1. Hair dyes are the dyes, used for hair colouring.
2. The purpose of this practice is to change the hair colour to a colour regarded as more fashionable or desirable and or to restore the original hair

colour after it has been discoloured by hairdressing processes or sun bleaching.

Types of Hair Dyes:

- 641. Permanent hair dyes.
- 642. Semi-permanent hair dyes.
- 643. Demi-permanent hair dyes.
- 644. Temporary hair dyes.

Permanent Hair Dyes:

1. Permanent hair colouring is usually carried out with oxidation dyes
2. The ingredients of these products include an oxidizing agent (usually hydrogen peroxide), coupling agents or couples (which are meta substituted derivatives of aniline) and the primary intermediate (which are aromatic para-compounds such as 1,4-diaminobenzene or 4-aminophenol or 2,5-diaminotoluene).
3. The process is essentially performed under basic conditions, for which ammonia is usually used.
4. The combination of H_2O_2 and the primary intermediate causes the natural hair to be lightened which provides a blank canvas for the dye.
5. Ammonia opens the hair shaft so that the dye can actually bond with the hair and ammonia speeds up the reaction of the dye with the hair.
6. The couplers (meta-substituted derivatives of aniline) are the chemical compounds that define the colour of the hair dye.
7. Various combinations of primary intermediates and couplers provide different shades of hair colours.

2. Semi-permanent hair dyes:

8. These dyes have smaller molecules than temporary and are therefore, able to partially penetrate the hair shaft.
9. That is why these colours can survive washing with typically 4-5 shampoos.
10. Semi-permanent hair dyes contain no or very low levels of developers, peroxide or ammonia and are thus, safer for damaged or fragile hair. However, they may still contain the toxic compound p-phenylenediamine or other such ingredients
11. The final colour of each strand of hair depends on its original colour and porosity, so there will be a large variations in shade across the whole head.
12. This gives a more natural result than that of a solid permanent colour.
13. Semi-permanent colour can lighten the hair..

3. Demi-permanent hair dyes:

14. These are in fact, permanent hair colours that contain an alkaline agent other than ammonia (e.g: ethanolamine, sodium carbonate) and the concentration of H_2O_2 in the developer may be lower than used in a permanent hair colour.
15. Since the alkaline agents employed in these colours are less effective in removing the natural pigment of hair than ammonia, these products provide no lightening of hair colour during dyeing.
16. As a result, they can not colour hair to a lighter shade than it was before dyeing and are less damaging to hair than permanent counterpart.

4. Temporary hair dyes:

- Temporary hair dyes are most oftenly used to colour hairs for special occasions such as weddings, costume parties etc. They are available in various forms, such as resins, shampoos, gels, sprays and foams.
- A temporary hair colour is typically brighter and more vibrant than semi permanent and permanent hair colour.
- The dye molecules in temporary hair colour are large and can not penetrate the cuticle layer.
- The colour particles remain absorbed (closely adherent) to the hair shaft and are easily removed with a single shampooing.

ADHESIVES

- Adhesives are the materials, usually in liquid or semi-liquid states, that adhere or bond items together.
- They come from either natural or synthetic sources. Although a large number of materials can be bonded by means of adhesives, they are specially useful for bonding thin materials:
- Adhesives cure (harden) by either evaporating a solvent or by chemical reactions that occur between two or more constituents.

TYPES OF ADHESIVES

adhesives are mainly classified into two classes.

- a. Non-reactive adhesives.
 - i) Drying adhesives
 - a) Solvent based adhesives
 - b) Polymer dispersion adhesives
 - ii) Pressure sensitive adhesives
 - iii) Contact adhesives
 - iv) Hot adhesives
- b. Reactive adhesives.

- i) Multiple adhesives
- ii) One part adhesives

Non reactive adhesives :

- These adhesives may be either of natural or synthetic origin.
- Drying adhesives, pressure sensitive adhesives, contact adhesives and hot adhesives are some examples of this class.
- Solvent base adhesives are a mixture of ingredients (typically polymers) dissolved in a solvent. White glue, contact adhesives and rubber cements are the members of the drying adhesive family.
- Polymer dispersion adhesive are also known as emulsion adhesives and are milky white dispersions often based on polyvinyl acetate (PVAc). They are extensively used in the wood working and packing industries; also used in fabrics and fabric based components and in the engineered products such as loudspeaker cones.
- Pressure Sensitive Adhesive (PSA): These adhesives form a bond by the application of light pressure to adhere the adhesive with the adherent. Once the adhesive and the adherent are in close proximity, molecular interactions, such as "Van der Waals forces" become involved in the bond, contributing significantly to its ultimate strength.
- Major raw materials for PSA's are acrylate based polymers.
- Contact Adhesives: These are used in strong bonds with high "shear-resistance" like laminates, such as bonding formica to a wooden counter and in footwear as in attaching outsoles to uppers.
- Examples of contact adhesives are, natural rubber and polychloroprene (Neoprene). It must be remembered that contact adhesives must be applied to both surfaces and allowed for some time to dry before the two surfaces are pushed together. Once the surfaces are pushed together, the bond forms very quickly
- Hot Adhesives: These are also known as hot melt adhesives or thermoplastics and are applied in molten form (65°C - 180°C range) which solidify on cooling to form strong bonds between a wide range of materials. Hot adhesives containing "ethylene vinyl acetate", are particularly popular for craft because of their ease of use and the wide range of common materials they can join. A glue-gun is one method of applying hot adhesive.
- The glue-gun melts the solid adhesive, then allows the liquid to pass through its barrel onto the material where it solidifies.
- Thermoplastic glue may have been invented around 1940 by "Proctor & Gamble" as a solution to water based adhesives commonly used in

packing at that time falling in humid climates, causing packages to open.

Reactive Adhesives:**Multiparts Adhesives:**

- These adhesives harden by mixing two or more components which chemically react.
- This reaction causes polymers to cross link into acrylics urethanes and epoxies.
- Commercially, there are several combinations of multi-component adhesives that are used in the industry.
- Some of these combinations are:
 - a) Polyester resin-Polyurethane resin.
 - b) Polyols-Polyurethane resins.
 - c) Acrylic Polymers-Polyurethane resins.
- The individual components of these adhesives do act as adhesive nature.
- These components, however, react with each other after being mixed and show full adhesion only on curing.

One Part Adhesives:

- These adhesives harden via a chemical reaction with an external energy source such as radiation heat or moisture.
- Light curing adhesives are generally acrylic based, and due to their rapid action, they are significantly used in electronics, telecommunications, medical, aerospace, glass and in optics.
- Heat curing adhesives include epoxies, urethanes and polyimides while moisture curing adhesives cure when they react with moisture present on the substrate surface or in the air.
- This type of adhesives include cyanoacrylates and urethanes.

MIX

- Dye is substance which adds value to product of substance for their cost.
- Pesticides are chemical substances used for destroying insect and other organisms harmful to cultivated plants or to be animals.
- Petrochemicals are relatively pure identifiable substances derived from petroleum and used in the chemical trade.
- A polymer are long chain giant organic compounds which are assembled from many smaller molecules.

- Condensation polymer formed through a condensation reaction, releasing small molecules as by-product.
- Industrial chemistry is the study of fundamental chemical processes used in industry for transferring raw material to useful commercial products for society.
- Lipids is mainly composed of a mixture of non volatile oil and solid wax.
- Nail varnish or nail polishes is a lacquer applied to human finger nails or toe nails to decorate or protect the nail plate.
- The most common type of nail polish remover contains acetone.

- Permanent hair colouring is usually in liquid or semi-liquid state, that adhere and bond items together.
- Adhesives are of two types
 - Non-reactive adhesive
 - Reacting adhesive
- Non-reactive adhesives may be
 - Natural
 - Synthetic origin
- Reactive adhesives chemically react with material, when harden.
- Cosmetic products apply to body, especially the face, to improve its appearance.
- Hair dye is usually soluble substances for staining or colouring.

Chap No.23 ENVIRONMENTAL CHEMISTRY

Four spheres of environment:

- Atmosphere
- Lithosphere
- Hydrosphere
- Biosphere

Atmosphere

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Exosphere

S.no	Sphere	Attitude in km	Temperature in degree
1	Troposphere	0-11	15 to -56
2	Stratosphere	11-50	-56 to -2
3	Mesosphere	50-85	-2 to -92
4	Thermosphere	85-500	-92 to 1200

Chemistry of troposphere

- It constitute 10% of atmosphere by height.
- It contains 80% atmosphere by mass.
- It contains
 - Nitrogen
 - Oxygen
 - Carbondioxide
 - Water

Chemical reaction in atmosphere

- The atmosphere contains SO_x and NO_x gases responsible for the acid rain.
- $4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$
- $\text{SO}_2 + \text{H}_2\text{O} + 1/2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4$
- $\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3$
- Acid rain is due to

- HNO_3
- H_2SO_4
- H_2CO_3

- The CO_2 present in the air is 0.036%.
- The lightening of the air and also in combustion engine of motor vehicles may also ignite reaction between stable molecules of nitrogen and oxygen producing carbon monoxide.

$$\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$$
- Incomplete combustion of the carbonaceous compounds result in the formation of carbon monoxide

$$\text{Hydrocarbon} + \text{O}_2 \rightarrow \text{CO} + \text{H}_2\text{O} + \text{energy}$$
- At concentration higher than 750 ppm, CO may cause of loss of consciousness and death occurs quickly.

Air pollution and their effects

- By volume Clean and dry contain
 - 78.09% nitrogen
 - 20.94% oxygen
 - 0.97% CO_2 , He, Kr, Ar and N_2O .
- Air pollutants:
 - CO
 - SO_2
 - NO_x
 - VOC's

Carbon monoxide

- $\text{HbO}_2 + \text{CO} \rightarrow \text{COHb} + \text{O}_2$
- The Fe binding sites in haemoglobin bind CO 320 times more tightly than oxygen.
- When concentration of CO is 100ppm, it may result in the headaches and shortness of breath.
- At concentration of the 750 ppm (0.1% of the air molecules), loss of consciousness and death occurs quickly.

Sulphur dioxide (SO₂);

- The main source of sulphur dioxide is combustion of coal and smelting of metals particularly copper.
- The sulphur content of the refined petroleum is generally quite low.
- The sulphur content of the coal is quite high.

Sulphur dioxide (SO₂) and volatile organic compounds:

- It plays an important role in formation of the smog.
- Smog is a brown blanket.
- Controlling smog formation requires NO_x and VOC's.
- Almost all NO_x is due to combustion of the fuel.
- Major source of VOC's are industrial processes, solvent utilization and on-road and non-road vehicles.

Ozone

- Ozone is present in the stratosphere.
- Ozone in the troposphere is a pollutant.
- Ozone affects us in quite low concentration, around 100ppb.

Automobiles, pollutants and the catalytic converter

- The major component in the exhaust of automobiles are
 - CO
 - NO
 - HC's
- In the reducing chamber, NO is reduced to N₂ by hydrogen and hydrogen is degraded at the surface of the rhodium catalyst by the action of water on unburned fuel molecules
- $\text{HC's} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{CO}$

- $2\text{NO} + 2\text{H}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$
- In the oxidation chamber, air is added to the CO and also unburned hydrocarbons are oxidized to CO₂ and H₂O at the surface of the Pt-Pd catalyst.
- $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$
- $\text{HC's} + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
- From automobiles, the three-way catalytic converter removes
 1. HC's
 2. NO
 3. CO

Industrial Smog

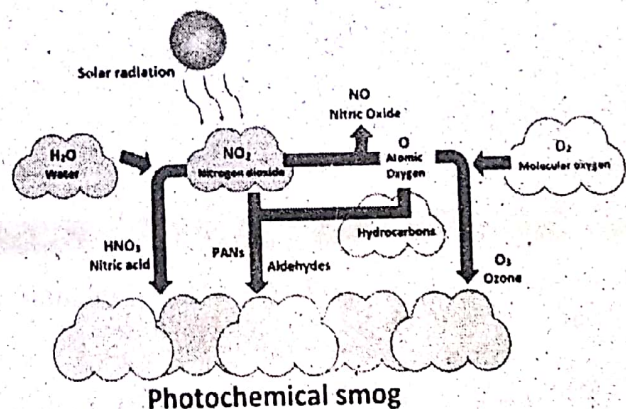
- Smog is the combination of smoke and fog.
- Smog causes brownish colorization in the atmosphere and thus reduces visibility in the area.
- Industrial smog is formed when exhaust pipes throw smoke and other materials into the air, particularly burning of the fossil fuels coal, oil and natural gas.
- CO₂ and H₂O is sometimes considered as pollutants.
- Burning of coal produces CO₂

$$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$$
- Most fossil fuels on combustion also produce sulphur dioxide

$$\text{S} + \text{O}_2 \rightarrow \text{SO}_2$$
- SO₂ is further oxidized to SO₃

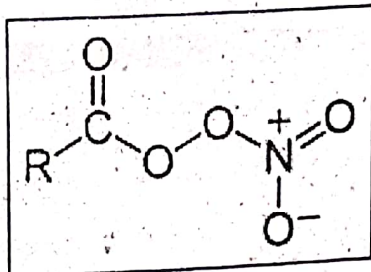
$$\text{SO}_2 + \text{O}_2 \rightarrow \text{SO}_3$$
- The SO₃ further reacts with water and forms H₂SO₄

$$\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$$
- The soot plays an important role in smog.
- Soot is primarily particles of carbon produced by burning of coal.
- 100ppm CO causes headache and shortness of breath.

Photochemical smog

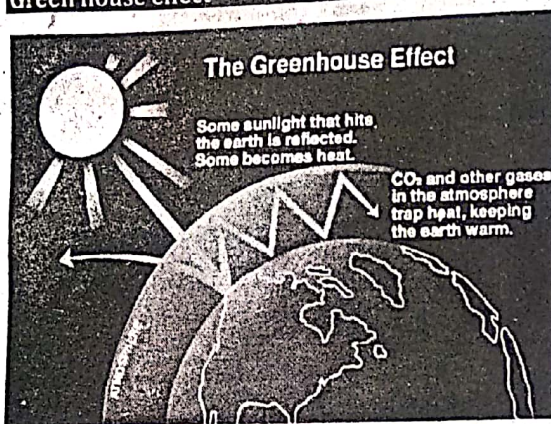
- Sunlight acts on air pollutants to produce photochemical smog.
- Photochemical smog is characterized by an accumulation of brown, hazy fumes, containing ozone and other oxidants.

- NO_2 absorb blue light of wavelength 400nm in splits into NO and O.
- $\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}$
- $\text{O}_2 + \text{O} \rightarrow \text{O}_3$
- $\text{O}_3 + \text{NO} \rightarrow \text{NO}_2 + \text{O}_2$
- The organic radical react with O_2 and produces acylperoxy radical which reacts with NO_2 and produce PAN.
- PAN



- The extent of smog formation depends on the reactivity of hydrocarbons with radical.

Green house effect



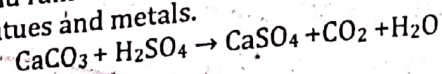
- The increase in the temperature of the earth surface is said to be green house effect.
- The suspected cause for green house effect is carbon dioxide.
- CO_2 contributes in green house effect 50%.
- Other gases effecting green house effect are
 - CH_4
 - CFC's
 - SO_2
 - NO_x

Acid Rain

- The term acid rain is referred to all precipitation like rain, dew and snow which is acidic.
- Natural water pH is 7.0.
- Acid rain pH is 5.6
- The atmosphere contains SO_x and NO_x gases responsible for the acid rain.
- $4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$
- $\text{SO}_2 + \text{H}_2\text{O} + 1/2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4$
- $\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3$

- Acid rain is due to
 - HNO_3
 - H_2SO_4
 - H_2CO_3

- The CO_2 present in the air is 0.036%.
- Heavy metals like Cu, Pb and Hg also dissolves by acid rain producing various toxic effects.
- Acid rain also corrodes buildings monuments, statues and metals.



Chemistry of Stratosphere: or ozone layer chemistry

Ozone formation

- $\text{O}_2 + \text{energy} \rightarrow 2\text{O}$
- $\text{O} + \text{O}_2 \rightarrow \text{O}_3$

Ozone destruction

- $\text{O}_3 + \text{energy} \rightarrow \text{O}_2 + \text{O}$
- $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$

- The concentration of ozone depends on the relative rates of the formation and destruction reactions.

Depletion of ozone layer

- Chlorine and bromine containing substances loss halo group which combines with ozones and break it, this is called ozone depletions
- Chlorofluoro carbon gas is used in
 - Refrigerators
 - Blowing agents for plastic foams
 - Propellents for aerosol spray
 - Solvents for cleaning micro electronic component.
- The halons have used as fire extinguishers.
- $\text{Rx} + \text{energy} \rightarrow \text{R} + \text{X}$
- $\text{X} + \text{O}_3 \rightarrow \text{XO} + \text{O}_2$
- $\text{XO} + \text{O} \rightarrow \text{X} + \text{O}_2$
- $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$

Water purification

- The water is purified mainly by
 - Distillation
 - Sand filtration
 - Charcoal filtration
 - Reverse osmosis

Types of water pollution

- Suspended solids and sediments
- Dissolved solids

Dissolved solids

- Dissolved salt is considered as pollutant if its concentration is greater than 500ppm
- The most common salt present in water is

- Carbonates
- Bicarbonates
- Sulphates
- Sulphides of calcium and magnesium
- Hardness of water depends primarily on Ca^{++} and Mg^{++} ion contents.

Source of water pollution

- Industrial effluents
- Domestic activities
- Agricultural wastes

Parameters of water analysis

Drinking water should be

- Odorless
- Tasteless
- Colourless
- Free from suspended solids
- Free from dissolved solids
- Free from excess of chlorides
- Free from sulphates and phosphate.
- Turbidity not more than 10 ppm.
- Free from disease causing bacteria
- Slightly alkaline of pH 7.0 to 8.5.

Parameters to check whether water is drinkable or not

- Biological oxygen demand (BOD).
- Chemical oxygen demand (COD).
- Total organic carbon (TOC).
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- pH
- alkalinity
- odour
- colour
- In BOD we add bacteria and COD we add chemicals.

Waste water treatment

Water from a lake or river, that must meet the qualities of drinking water, undergoes a purifying treatment, involving several steps.

- First, the undissolved (floating and visible) solid materials, if present in water, are removed. Coarse objects are removed by running the water through screens/filters.
- The finer, colloidal particles that make water turbid, can not be removed by simple filtration. So a flocculating agent that is a substance that forms large gelatinous particles, is added. The common

flocculating agent is aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3$, often referred to as alum, some lime, $\text{Ca}(\text{OH})_2$, is generally also added so that precipitate of aluminium hydroxide, $\text{Al}(\text{OH})_3$ which has the desired gelatinous form, is produced.

- $\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca}(\text{OH})_2 \rightarrow 2\text{Al}(\text{OH})_3 + 2\text{CaSO}_4$
- This precipitate traps both inorganic solid particles and bacteria in the large curd like particles. These particles are then easily removed by filtration through a sand-bed or charcoal
- After filtration through the sand-bed, the water is usually treated with chlorine to kill remaining bacteria and other microbes. Chlorination is the widely used method to disinfect water for longer duration of time.
- The reactions involved are

$$\text{H}_2\text{O} + \text{Cl}_2 \rightarrow \text{H}^+ + \text{Cl}^- + \text{HOCl}$$
- HOCl is weak acid and partially dissociates.

$$\text{HOCl} \rightarrow \text{H}^+ + \text{OCl}^-$$

$$\text{HOCl} \rightarrow [\text{O}] + \text{HCl}$$
- It is this nascent oxygen, $[\text{O}]$, that gives taste and odour to the water. Thus air is sometimes blown through the water, i.e. the water is aerated to improve its odour and taste. A fluoride compound is added in some plants to help fight tooth decay. The result of thorough water treatment operation is water, that is as good as new.

Goals of Green Chemistry

The goal of "Green Chemistry" perspective include the following:

- To reduce adverse environmental impacts by appropriate and innovative choice of materials and their chemical transformations.
- Develop processes based on renewable (plant-based) rather than non-renewable (fossil carbon-derived) raw materials.
- To develop processes that are less prone to obnoxious chemical releases, fires and explosions.
- To minimize byproducts in chemical transformations through redesign of reactions and reaction sequences. In other words, to achieve better "Atom economy"
- % Atom economy =
$$\frac{\text{Formula weight of the product}}{\text{sum of the formula weights of all the reactants}} \times 100$$

 (Good atom economy means most of the atoms of the reactants are incorporated in the desired products and only small amounts of unwanted byproducts are formed and hence lesser problems of waste disposal or waste treatment)
- To develop products that are less toxic or which require less toxic raw materials/feed stocks
- To develop products that degrade more readily in environment than the current products.

- To reduce the requirements for hazardous or environmentally persistent solvents and extractants in chemical processes.
- To improve energy efficiency by developing low temperature and low pressure processes by using new/improved catalysts.
- To develop efficient and reliable methods to monitor processes (e.g. monitoring reactions and releases) for improved control.

MIX

- Environmental chemistry is the branch of chemistry which deals with chemical and biochemical occurrence in nature.
- Pollutant is any substance which contaminate our environment.
- Atmosphere is big tank of gases, surrounding the earth's surface.
- The term acid rain is referred to all precipitations which is more acidic than natural water.

- Rain
- snow
- dew
- The pH of natural water is 7.0.
- Smog is combination of smoke and fog.
- Water is an important natural resource on this planet.
- An important aspect of water quality is the amount of dissolved oxygen in it.
- The term green chemistry is defined as the invention, design and application of chemical product and process to reduce or to eliminate the use and generation of hazardous substances.
- The smog consisting of high concentration of petrochemical oxidants is known as petrochemical or oxidizing smoke.
- Increase concentration of CO₂ increases the earth's temperature, by greenhouse effect. This in turn result the climate changes and global warming.

Chap No. 24 ANALYTICAL CHEMISTRY

- Analytical chemistry is the branch of chemistry that deals with the identification of substances and finding their weights.
- A set of experiments used to know about the quality of the substance is called qualitative analysis.
- The methods used to find the quantity of substance is called quantitative analysis.
- Analytical chemistry deals with both qualitative and quantitative analysis.
- Identification of acid and basic radicals in a salt involves qualitative analysis.
- Volumetric analysis (titrations) and gravimetric analysis are quantitative chemical analysis.

- Organic compound on burning produces CO₂ and H₂O.
- The water is absorbed by a sample of Magnesium perchlorate [Mg(ClO₄)₂] of known mass.
- The carbon dioxide is absorbed in a known mass of KOH.
- $\%C = \frac{\text{mass of CO}_2}{\text{mass of org. compound}} \times \frac{12}{44} \times 100$
- $\%H = \frac{\text{mass of H}_2\text{O}}{\text{mass of org. compound}} \times \frac{2.02}{18.02} \times 100$
- $\%O = 100 - (\%C + \%H)$
- If percentage of oxygen comes out to be zero, it means the organic compounds does not contain oxygen.

Combustion

- Burning of substance in the presence of oxygen is called combustion.
- Combustion is exothermic process in which heat energy is evolved.
- Combustion process is used for only those compounds which contain C, H and O.
- Combustion cannot be used for those compounds which contain elements other than C, H and O.
- In combustion process a n=known weight of organic compound is mixed with CuO.
- The sample is taken in platinum boat at 850°C.

Calculation of Empirical formulae

- Empirical formula gives us a simple whole number ratio.
- Moles of C = $\frac{\% \text{ of C}}{\text{At. mass of C}}$
- Moles of H = $\frac{\% \text{ of H}}{\text{At. mass of H}}$
- Moles of O = $\frac{\% \text{ of O}}{\text{At. Mass of O}}$
- Simplest ration between the number of moles of each elements by the smallest number of moles.
- If the ration is not in whole number ration, then it is multiplied by such number to get whole number ratio.
- The empirical formula of Aspirin is C₉ H₈ O₄.

- In inorganic chemistry, empirical formula is enough informative to distinguish between one substance from another.
- Molecular formula in organic chemistry may represent more than one substance..
- C_2H_6O is molecular formula of Ethanol and Dimethyl ether.
- To represent a particular organic substance we use structural formula.
- Modern methods of analysis include
 - Infrared spectrophotometry
 - Ultraviolet spectrophotometry
 - Visible spectrophotometry
 - Atomic absorption spectrophotometry
 - Atomic emission spectrophotometry
 - Mass spectrometry
- Advantages of modern methods of analysis
 - Small amount of chemical required
 - No chemical wastage
 - Rapid method
 - Less time consumed
 - More accurate result
 - Simple method

Spectroscopy

- For structural formula of compound three aspects are considered;
 - Physical properties of compound
 - Chemical properties of compound
 - Instrumental methods of analysis
- Ethanol at room temperature is liquid while dimethyl ether is gas.
- Boiling point of ethanol is 341K.
- Boiling point of dimethyl ether 248K.
- An atom or group of atom that gives certain characteristics properties to the compound.
- Different compounds having the same molecular formula but different functional groups behaves differently to same reactant.
- Ethanol reacts with sodium metal liberating hydrogen while dimethyl ether do not react with it.
- Organic compounds absorb energy on interaction with electromagnetic radiations (emr).
- $E = hf = h\nu/\lambda = hc/\lambda$
- Cosmic > Gammas > X-rays > U.V > Vis > IR > Micro > Radio
- During the interaction of organic compounds with electromagnetic radiations certain wavelengths are absorbed, which excites the molecules/atoms to higher energy level.
- In atoms the transition results due to change in the distribution of electrons.

- In molecules along with changes electromagnetic distribution, changes in the molecular rotations and bond vibrations (stretching, bending) also occurs.
- The bond vibration and rotation of molecules need less energy, i.e. in IR region.
- The electronic excitation needs more energy i.e. uv/vis region.
- The instrument used to record the wavelengths absorbed and the concentration of the absorbing species is called spectrophotometer.
- Spectrophotometry is used both for qualitative and quantitative analysis.

Spectroscopic method: Infrared

- In IR spectroscopy organic compounds are exposed to weak radiations in the range 667-5000 cm^{-1} .
- The unit of wave number is cm^{-1} .
- Vibrations may be stretching or bending.
- In stretching the bond angle does not change but only the distance between the atom changes.
- In bending vibrations interatomic distance do not change but the angle between the atoms are changes.
- Stretching vibrations may be symmetric or asymmetric.
- Bending vibrations may be:
 - Rocking
 - Scissoring
 - Twisting
 - Wagging
- Wave number is plotted on x-axis and %transmittance on y-axis.
- Each dip in spectrum is called band or peak.
- A 100% transmittance means no absorption.
- No two different organic compounds would give rise to identical spectra.
- IR region is divided into two:
 - a) 600-1500 cm^{-1} → finger print region
 - b) 1500-4000 cm^{-1} → functional group region
- Two different compounds will give different absorptions peaks in finger print region.
- Different functional groups show absorptions at different frequencies in functional group region.
- The presence of absorption peak at positions where the compound does not absorb indicates the presence of impurities.
- The presence of cyclohexanone is readily detected in cyclohexanol by the intense carbonyl bond.
- The oxidation of secondary alcohol to ketone is accompanied by the disappearance of the O-H bond near 3600 cm^{-1} and the appearance of C=O band near 1715 cm^{-1} .

Ultraviolet and visible spectrophotometry

- In uv/vis spectroscopy radiation having wavelength in the range 200-800 nm are used.
- Uv/vis radiations are more energetic and therefore, can change the distribution of loosely bonded pi bond and non-bonded electrons in atoms/molecules.
- All matters absorb energy in this region because all matters contain electrons.
- The absorption is according to Beer-Lambert's Law
 - $A = \epsilon cl$, here
 - A is absorbance
 - ϵ is molar absorptivity or molar extinction coefficient
 - c is concentration of solution in mole per litre.
 - l is path length of solution in centimetre.
- ϵ is a constant characteristic of constant solute at a given wavelength.
- Uv/vis spectrophotometry is used for both qualitative and quantitative analysis.
- For quantitative analysis, we use Beer Lambert Law.
- The absorption of uv-vis light by a solution kept in a quartz cell of known length is directly proportional to the concentration of solution.
- Solutions of different concentration are prepared and are introduced into the uv-vis spectrophotometer in order to record their absorbance.
- A graph is constructed by plotting the concentrations on x-axis and absorbance on y-axis. The graph is called working curve.
- During this experiment a selected wave length λ_{max} at which maximum absorption occurs is used throughout the study.
- When a solution of unknown concentration is placed in the spectrophotometer, its concentration is displayed on the screen.
- UV light ranges from 10-400 nm and visible light from 400-800 nm.
- The electronic transition that are associated with the absorption with the absorption of uv/vis radiation, are of four types,
 - a) $\sigma \rightarrow \sigma^*$
 - b) $n \rightarrow \sigma^*$
 - c) $\pi \rightarrow \pi^*$
 - d) $n \rightarrow \pi^*$
- $\sigma \rightarrow \sigma^*$ transition occur in a saturated hydrocarbon such as - CH_3 which contain only sigma bond.
- $\sigma \rightarrow \sigma^*$ requires more energy.
- Energy Order: $\sigma \rightarrow \sigma^* > n \rightarrow \sigma^*$
- C-C bond absorbs 135 nm.
- C-H bond absorbs 125 nm.

- $n \rightarrow \sigma^*$ transition occur in a saturated molecule containing hetero atoms.
- $n \rightarrow \sigma^*$ transition requires less energy than $\sigma \rightarrow \sigma^*$ transition.
- $\pi \rightarrow \pi^*$ transition occurs in molecule, containing double bond or triple bond or aromatic molecule.
- Ethylene absorbs at 171 nm.
- A conjugated system absorbs at much longer wavelength.

Butadiene absorbs at 217 nm.

- $n \rightarrow \pi^*$ transition occurs in molecule, containing double bond or triple bonds involving hetero atoms.
- Transition metal complexes are usually coloured due to d-d transition.
- When a compound absorbs violet light (400-435 nm), it reflects all the remaining six colour which electively appear as a single colour called complementary colour.
- Complementary colour of violet colour is yellow green.
- From the uv-vis spectrum of transition metal complex, the colour of compound can be predicted.

Nuclear Magnetic resonance (NMR):

- Like electrons atomic nucleus also spin about an axis.
- Atomic nucleus behaves like tiny magnet, as the spinning charged bodies produce magnetic field.
- The nuclear spin is quantised, therefore, the magnetic moment of nucleus is also quantised.
- In a proton the spin quantum number is $\frac{1}{2}$.
- Other nuclei which contain odd number of protons or neutrons or both also have a spin quantum number = $\frac{1}{2}$ e.g. C^{13} , N^{15} , F^{19} , P^{31} .
- Nuclei which have even number of protons and neutrons have zero spin and have zero magnetic movement. e.g. C^{12} and O^{16} . Such nuclei are invisible in NMR spectrometry.
- In the absence of magnetic field, the spin states of a nucleus have equal energies.
- If a magnetic field is applied, the spin states are no longer of equal energy, two states are produced.
- The two states are:
 - Lower energy state ($+\frac{1}{2}$)
 - High energy state ($-\frac{1}{2}$)
- Proton with magnetic field aligned with the applied field is at a lower energy than that which aligns against the field.
- Nuclei with magnetic field can absorb energy and change their spin state. This phenomenon is called flipping.
- The quantity of energy absorbed depends on the energy gap between the two states.

Since 2016

$$\rightarrow E_{\text{absorbed}} = E_{(-1/2)} - E_{(+1/2)}$$

- Energy absorbed belongs to radio frequency.
- The absorption of energy is recorded on a chart paper.
- When a sample is placed in NMR spectrophotometer, the magnetic field is varied and energy of a specific frequency is absorbed.

Position of signals (chemical shift)

- NMR spectrophotometer can differentiate between protons of different environments.
- Protons of the same environment are called equivalent protons.
- All the six protons of benzene are equivalent, therefore the NMR spectrum of benzene shows a single peak.
- Ethanol gives three peaks in NMR spectrum.
- The area under the peak is directly proportional to the number of protons.
- For taking the NMR spectrum of a substance a little amount of TMS is added to it.
- TMS means tetramethyl silane $(\text{CH}_3)_4\text{Si}$.
- TMS is chosen as standard.
- NMR spectrum is a plot of absorption on y-axis and chemical shift on x-axis.
- For TMS the value of chemical shift has been chosen arbitrarily.
- Chemical shift of other compounds are compared with TMS.
- All other compounds have chemical shift (δ) value higher than zero.
- TMS has been chosen as a standard because its all protons are equivalent and show absorption at lowest δ value.
- Chemical shift is expressed as delta (δ) or tau (τ) scale.
- NMR spectrum is rectangular chart paper with a linear scale of δ (delta) usually arranging from 0 to 12 ppm, the TMS signal is taken as $\delta = 0$.
- $\delta = \text{observed shift from TMS in (Hz) / Operating frequency of spectrophotometer (Hz)} \times 10^6 \text{ ppm}$.
- $\delta + \tau = 1$
- Usually ppm scale is used, where TMS is at 10 ppm.
- Protons with greater electron clouds are called less deshielded protons and they require higher frequency for flipping from lower energy to lower energy states. Such peaks appear as upfield (lower δ value).
- Protons in the vicinity of higher electronegative atoms like Cl, F, O etc have low electron densities around them and require little energy for flipping. Such protons are called deshielded protons. Such protons show Peak at higher δ value (downfield).
- For the value of δ , the different protons of a compound can be differentiated from one another.

Atomic Emission And Absorption Spectra

- When a metal is strongly heated, it starts glowing.
- The light emitted from the metal when passed through prism forms a continuous spectrum (emission spectrum) from violet to red.
- The emission spectra of atoms in gas phase gives line emission spectrum.
- Each element has a characteristic line spectrum.
- When hydrogen gas is taken in a discharge tube under low pressure it emits blue light.
- The blue light by hydrogen atoms is emitted by atoms when they go from excited to ground state.
- When blue light of hydrogen is passed through prism, four bright lines against dark background are produced:
 - Violet $\rightarrow 410.1 \text{ nm} \rightarrow 3 \text{ to } 2 \text{ shell transition}$
 - Blue-violet $\rightarrow 434.0 \text{ nm} \rightarrow 4 \text{ to } 2 \text{ shell transition}$
 - Blue-green $\rightarrow 486.0 \text{ nm} \rightarrow 5 \text{ to } 2 \text{ shell transition}$
 - Red $\rightarrow 656.2 \text{ nm} \rightarrow 6 \text{ to } 2 \text{ shell transition}$
- Hydrogen spectrum give lines in all series;
 - Lyman $\rightarrow \text{U.V}$
 - Balmer $\rightarrow \text{Vis}$
 - Paschen $\rightarrow \text{Near IR}$
 - Brackett $\rightarrow \text{Mid IR}$
 - Pfund $\rightarrow \text{Far IR}$
- Wavelength of different lines of Balmer series are given by following formula:

$$1/\lambda = R_H [1/(2)^2 - 1/(n)^2]$$
- R_H is Rydberg constant and its value is $2.18 \times 10^{-18} \text{ J}$.
- Sodium gives yellow flame to Bunsen flame.
- Sodium produce two closely lights:
 - $D_1 \rightarrow 589 \text{ nm}$
 - $D_2 \rightarrow 589.6 \text{ nm}$
- For every element there is unique emission and absorption spectrum.
- Emission or absorption atomic spectra are used as finger print to identify the elements.

Flame photometer:

- Atomic absorption spectrometry is used for the analysis of elements.
- Flame photometer is widely used emission spectroscopic technique.
- Flame photometer is used to find the concentration of Ni, Na K etc.
- An aqueous analyte is introduced into flame. Water evaporates and solid salt is left behind.
- The salt breaks into constituent atoms.
- The atoms go to vapour states.

- Some of the atoms in the flame get excited but majority of them are in ground state.
- The gases atoms get excited in the flame. The excited atom loses energy of characteristic wavelength, which is dispersed by a grating or prism and detected in the spectrophotometer.
- The intensity of light emitted by the atoms is directly proportional to the concentration of analyte.
- For the analysis of different elements, different types of lamps are used.
- Each atom shows absorption of particular wavelength.
- The sample of unknown concentration is aspirated into the flame and its concentration is read from instrument.
- Lighter ions (low m/e) deflect to larger extent than heavier ions.
- At the same time only one kind of ions strikes the detector.
- By positive ions, electric signals are produced which is later on amplified by an amplifier.
- The intensity of the electric signal is directly proportional to the number of ions striking the detector.
- Mass spectrum is a chart in which m/e is taken on x-axis and relative abundance on y-axis.
- Three isotopes of neon with respect to their abundance are:
 - ✓ $^{20}\text{Ne} \rightarrow 90.92\%$
 - ✓ $^{21}\text{Ne} \rightarrow 0.57\%$
 - ✓ $^{22}\text{Ne} \rightarrow 8.82\%$
- Neon-21 is the least abundant isotope.
- Neon-20 is more abundant isotope ($21 \rightarrow 22 \rightarrow 20$)
- Chlorine isotopes with their abundance are:
 - ✓ $\text{Cl-35} \rightarrow 75\%$
 - ✓ $\text{Cl-37} \rightarrow 25\%$

Mass Spectrometry

- Atomic and molecular mass are determined by mass spectrometry.
- Mass spectrometer is a very highly sensitive instrumental technique.
- The sample is injected as a gas into the ionization chamber.
- Electrons, come from the electron gun collide with the sample atoms or molecules.
- The collisions electrons from the sample atoms or molecules are knocked out and they become positive ions.
- The positive ions are accelerated by the electric field.
- The ions in the magnetic field deflect in circular path.
- Different ions now separate on the basis of m/e ratio.
- When molecule is introduced into mass spectrometer, the molecular ion (M^+) is produced due to loss of electron.
- In addition to the molecular ion, more ions are produced due to fragmentation of the molecule.
- Fragmentation occurs due to rupture of chemical bonds.
- The fragmentation pattern of a molecule gives an idea of the structure of the molecule.
- The mass spectrometry is very helpful in the identification of molecular mass is well.

The End

1511. A $\frac{2.0}{10.0} \times \frac{2 \times 27}{150} \times 100$
 Amount of $\text{Cl}^{35} = \frac{75}{100} = 0.75$
 Amount of $\text{Cl}^{37} = \frac{25}{100} = 0.25$
 Average atomic weight =
 (Amount) (At. Mass of 1st Isotope) + (Amount) (At. mass of 2nd Isotope)
 = (0.75) (35) + (0.25)

(37) = 26.25 + 9.25 = 35.5

1512. B
 1513. D
 1514. C
 1515. D
 1516. B
 1517. A
 1518. B
 1519. C

1520. A
 1521. A
 1522. A 24
 1523. B Proton mass
 1524. A
 1525. D
 1526. D

USEFUL STUFFS

LIST OF ELECTRON CONFIGURATIONS OF ELEMENTS

1	Hydrogen	1s ¹	60	Neodymium	[Xe]4f ⁴ 6s ²
2	Helium	1s ²	61	Promethium	[Xe]4f ⁵ 6s ²
3	Lithium	[He]2s ¹	62	Samarium	[Xe]4f ⁶ 6s ²
4	Beryllium	[He]2s ²	63	Europium	[Xe]4f ⁷ 6s ²
5	Boron	[He]2s ² 2p ¹	64	Gadolinium	[Xe]4f ⁷ 5d ¹ 6s ²
6	Carbon	[He]2s ² 2p ²	65	Terbium	[Xe]4f ⁷ 6s ²
7	Nitrogen	[He]2s ² 2p ³	66	Dysprosium	[Xe]4f ⁹ 6s ²
8	Oxygen	[He]2s ² 2p ⁴	67	Holmium	[Xe]4f ¹⁰ 6s ²
9	Fluorine	[He]2s ² 2p ⁵	68	Erbium	[Xe]4f ¹¹ 6s ²
10	Neon	[He]2s ² 2p ⁶	69	Thulium	[Xe]4f ¹² 6s ²
11	Sodium	[Ne]3s ¹	70	Ytterbium	[Xe]4f ¹⁴ 6s ²
12	Magnesium	[Ne]3s ²	71	Lutetium	[Xe]4f ¹⁴ 6s ²
13	Aluminum	[Ne]3s ² 3p ¹	72	Hafnium	[Xe]4f ¹⁴ 5d ² 6s ²
14	Silicon	[Ne]3s ² 3p ²	73	Tantalum	[Xe]4f ¹⁴ 5d ³ 6s ²
15	Phosphorus	[Ne]3s ² 3p ³	74	Tungsten	[Xe]4f ¹⁴ 5d ⁴ 6s ²
16	Sulfur	[Ne]3s ² 3p ⁴	75	Rhenium	[Xe]4f ¹⁴ 5d ⁵ 6s ²
17	Chlorine	[Ne]3s ² 3p ⁵	76	Osmium	[Xe]4f ¹⁴ 5d ⁶ 6s ²
18	Argon	[Ne]3s ² 3p ⁶	77	Iridium	[Xe]4f ¹⁴ 5d ⁷ 6s ²
19	Potassium	[Ar]4s ¹	78	Platinum	[Xe]4f ¹⁴ 5d ⁹ 6s ¹
20	Calcium	[Ar]4s ²	79	Gold	[Xe]4f ¹⁴ 5d ¹⁰ 6s ¹
21	Scandium	[Ar]3d ¹ 4s ²	80	Mercury	[Xe]4f ¹⁴ 5d ¹⁰ 6s ²
22	Titanium	[Ar]3d ² 4s ²	81	Thallium	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹
23	Vanadium	[Ar]3d ³ 4s ²	82	Lead	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ²
24	Chromium	[Ar]3d ⁵ 4s ¹	83	Bismuth	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ³
25	Manganese	[Ar]3d ⁵ 4s ²	84	Polonium	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴
26	Iron	[Ar]3d ⁶ 4s ²	85	Astatine	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵
27	Cobalt	[Ar]3d ⁷ 4s ²	86	Radon	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶
28	Nickel	[Ar]3d ⁸ 4s ²	87	Francium	[Rn]7s ¹
29	Copper	[Ar]3d ¹⁰ 4s ¹	88	Radium	[Rn]7s ²
30	Zinc	[Ar]3d ¹⁰ 4s ²	89	Actinium	[Rn]6d ¹ 7s ²
31	Gallium	[Ar]3d ¹⁰ 4s ² 4p ¹	90	Thorium	[Rn]6d ² 7s ²
32	Germanium	[Ar]3d ¹⁰ 4s ² 4p ²	91	Protactinium	[Rn]5f ² 6d ¹ 7s ²
33	Arsenic	[Ar]3d ¹⁰ 4s ² 4p ³	92	Uranium	[Rn]5f ³ 6d ¹ 7s ²
34	Selenium	[Ar]3d ¹⁰ 4s ² 4p ⁴	93	Neptunium	[Rn]5f ⁴ 6d ¹ 7s ²
35	Bromine	[Ar]3d ¹⁰ 4s ² 4p ⁵	94	Plutonium	[Rn]5f ⁶ 7s ²
36	Krypton	[Ar]3d ¹⁰ 4s ² 4p ⁶	95	Americium	[Rn]5f ⁷ 7s ²
37	Rubidium	[Kr]5s ¹	96	Curium	[Rn]5f ⁷ 6d ¹ 7s ²

NUMS, MDCAT, NMDCAT, FMDC, ETEA MED, ETEA ENG & KMU CAT

38	Strontium	[Kr]5s ²	97	Berkelium	[Rn]5f ⁷ 7s ²
39	Yttrium	[Kr]4d ¹ 5s ²	98	Californium	[Rn]5f ¹⁰ 7s ²
40	Zirconium	[Kr]4d ² 5s ²	99	Einsteinium	[Rn]5f ¹¹ 7s ²
41	Niobium	[Kr]4d ⁴ 5s ¹	100	Fermium	[Rn]5f ¹² 7s ²
42	Molybdenum	[Kr]4d ⁵ 5s ¹	101	Mendelevium	[Rn]5f ¹³ 7s ²
43	Technetium	[Kr]4d ⁵ 5s ²	102	Nobelium	[Rn]5f ¹⁴ 7s ²
44	Ruthenium	[Kr]4d ⁷ 5s ¹	103	Lawrencium	[Rn]5f ¹⁴ 7s ² 7p ¹
45	Rhodium	[Kr]4d ⁸ 5s ¹	104	Rutherfordium	[Rn]5f ¹⁴ 6d ¹ 7s ²
46	Palladium	[Kr]4d ¹⁰	105	Dubnium	[Rn]5f ¹⁴ 6d ¹ 7s ²
47	Silver	[Kr]4d ¹⁰ 5s ¹	106	Seaborgium	[Rn]5f ¹⁴ 6d ² 7s ²
48	Cadmium	[Kr]4d ¹⁰ 5s ²	107	Bohrium	[Rn]5f ¹⁴ 6d ² 7s ²
49	Indium	[Kr]4d ¹⁰ 5s ² 5p ¹	108	Hassium	[Rn]5f ¹⁴ 6d ² 7s ²
50	Tin	[Kr]4d ¹⁰ 5s ² 5p ²	109	Meitnerium	[Rn]5f ¹⁴ 6d ² 7s ²
51	Antimony	[Kr]4d ¹⁰ 5s ² 5p ³	110	Darmstadtium	[Rn]5f ¹⁴ 6d ² 7s ²
52	Tellurium	[Kr]4d ¹⁰ 5s ² 5p ⁴	111	Roentgenium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ¹
53	Iodine	[Kr]4d ¹⁰ 5s ² 5p ⁵	112	Copernium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ²
54	Xenon	[Kr]4d ¹⁰ 5s ² 5p ⁶	113	Nihonium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ¹
55	Cesium	[Xe]6s ¹	114	Flerovium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ²
56	Barium	[Xe]6s ²	115	Moscovium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ³
57	Lanthanum	[Xe]5d ¹ 6s ²	116	Livermorium	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁴
58	Cerium	[Xe]4f ¹ 5d ¹ 6s ²	117	Tennessine	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁵
59	Praseodymium	[Xe]4f ³ 6s ²	118	Oganesson	[Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁶

SYSTEM OF UNITS

Physical quantity	Name in Units	Symbol	Physical quantity	Name in Units	Symbol
Length	Metre	m	Pressure	atmosphere	Atm (101.325 kPa)
Mass	kilogram	kg		torr	mmHg(133.32Pa)
Time	second	s	Energy	calorie	cal(4.184J)
Temperature	Kelvin	K		electron volt	ev(1.6022x10 ⁻¹⁹ J)
Electrical current	ampere	A	Temperature	degree celsius	°C (K - 273.15)
Luminous intensity	candela	Cd	Concentration	molarity	M (mol/L or Mol/dm ³)
Amount of substance	mole	Mol			
Volume	cubic metre	M ³			
Length	angstrom	Å (0.1 nm)			

COMMON DERIVED UNITS IN SI

Physical Quantity	Name in Unit	Symbol
Energy	joule	J(kg-m ² /s ²)
Frequency	hertz	Hz(cycles/s)
Force	newton	N(kg-m/s ²)
Pressure	pascal	Pa (N/M ²)
Power	watt	W(J/s)
Electrical charge	coulomb	C(amp-s)
Electrical potential	volt	V(J/c)
Electrical resistance	Ohm	Ω(V/amp)
Electrical conductance	siemens	S(amp/V)
Electrical capacitance	farad	F(C/V)

FRACTION AND MULTIPLIES FOR USE IN SI

Fraction and Multi lies for Use in SI			
exa, E	10 ¹⁸	deci, d	10 ⁻¹
peta, P	10 ¹⁵	centi, c	10 ⁻²
tera, T	10 ¹²	milli, m	10 ⁻³
giga, G	10 ⁹	micro, μ	10 ⁻⁶

hecto, h	10^2	pico, p	10^{-9}
deca, da	10^1	femto, f	10^{-12}
		atto, a	10^{-15}
			10^{-18}

CONSTANTS

Speed of light in vacuum (c)	$c = 2.99792458 \times 10^8 \text{ m/s}$
Charge on an electron (q_e)	$q_e = 1.6021892 \times 10^{-19} \text{ C}$
Rest mass of electron (m_e)	$m_e = 9.109534 \times 10^{-28} \text{ g}$
	$m_e = 5.4858026 \times 10^{-4} \text{ amu}$
Rest mass of proton (m_p)	$m_p = 1.6726485 \times 10^{-24} \text{ g}$
	$m_p = 1.00727647 \text{ amu}$
Rest mass of neutron (m_n)	$m_n = 1.6749543 \times 10^{-24} \text{ g}$
	$m_n = 1.00865012 \text{ amu}$
Faraday's constant (F)	$F = 96484.56 \text{ C/mol}$
Planck's constant (h)	$h = 6.626176 \times 10^{-34} \text{ J-s}$
Ideal gas constant (R)	$R = 0.0820568 \text{ L-atm/mol-K}$
	$R = 8.31441 \text{ J/mol-K}$
Atomic mass unit (amu)	$1 \text{ amu} = 1.6605655 \times 10^{-24} \text{ g}$
Boltzmann's constant (k)	$k = 1.380662 \times 10^{-23} \text{ J/K}$
Avogadro's constant (N_A)	$N_A = 6.022045 \times 10^{23} \text{ mol}^{-1}$
Rydberg constant (R_H)	$R_H = 1.09737318 \times 10^7 \text{ m}^{-1}$
	$= 1.09737318 \times 10^{-2} \text{ nm}^{-1}$
Molar volume of gas at s.t.p.	$V_m = 2.24 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$
Heat capacity of water	$c = 75216 \text{ J/mol-K}$

CONVERSION FACTORS

Energy	$1 \text{ J} = 0.2390 \text{ cal} = 10^7 \text{ erg}$ $1 \text{ cal} = 4.184 \text{ J}$ $1 \text{ eV/atom} = 1.6021892 \times 10^{-19} \text{ J/atom} = 96.484 \text{ kJ/mol}$
Temperature	$K = ^\circ\text{C} + 273.15$ $^\circ\text{C} = 5/9 (F - 32)$ $^\circ\text{F} = 9/5 (C) + 32$
Pressure	$1 \text{ atm} = 760 \text{ mmHg} = 760 \text{ torr} = 101.325 \text{ kPa}$
Mass	$1 \text{ kg} = 2.2046 \text{ lb}$ $1 \text{ lb} = 453.59 \text{ g} = 0.45359 \text{ kg}$ $1 \text{ oz} = 0.03250 \text{ kg} = 28.350 \text{ g}$ $1 \text{ ton} = 2000 \text{ lb} = 907.185 \text{ kg}$ $1 \text{ tone (metric)} = 1000 \text{ kg} = 2204.62 \text{ lb}$
Volume	$1 \text{ mL} = 0.001 \text{ L} = 1 \text{ cm}^3$ $1 \text{ oz (fluid)} = 0.031250 \text{ qt} = 0.029573 \text{ L}$ $1 \text{ qt} = 0.946326 \text{ L}$ $1 \text{ gal} = 0.946 \text{ L}$
Length	$1 \text{ mile} = 1.60934 \text{ km}$ $1 \text{ in.} = 2.54 \text{ cm}$ $10 \text{ mm} = 1 \text{ cm}$ $1000 \text{ mm} = 1 \text{ m}$ $1000 \text{ m} = 1 \text{ km}$ $1 \text{ m} = 39.37 \text{ in.}$ $\text{\AA} = 10^{-10} \text{ m} = 10^{-8} \text{ cm}$

SOLUBILITY TABLE

	F^-	Cl^-	Br^-	I^-	O^{2-}	S^{2-}	OH^-	NO_3^-	CO_3^{2-}	SO_4^{2-}	CH_3COO^-
H^+	S	S	S	S	S	S	S	S	S	S	S
Na^+	S	S	S	S	S	S	S	S	S	S	S
K^+	S	S	S	S	S	S	S	S	S	S	S

Ag ⁺	S	S	S	S	S	S	-	S	S	-	S
Mg ²⁺	I	S	S	S	I	I	-	S	I	I	I
Ca ²⁺	I	S	S	S	I	D	I	S	I	S	S
Ba ²⁺	I	S	S	S	I	D	I	S	I	I	S
Fe ²⁺	I	S	S	S	S	D	S	S	I	I	S
Co ²⁺	S	S	S	-	I	I	I	S	I	S	I
Ni ²⁺	S	S	S	S	I	I	I	S	I	S	S
Cu ²⁺	S	S	S	S	I	I	I	S	I	S	S
Zn ²⁺	S	S	S	-	I	I	I	S	I	S	S
Hg ²⁺	D	S	I	I	I	I	I	S	I	D	S
Cd ³⁺	S	S	S	S	I	I	I	S	I	S	S
Sn ²⁺	S	S	S	S	I	I	I	S	I	S	S
Pb ²⁺	I	I	I	I	I	I	I	S	I	I	S
Mn ²⁺	S	S	S	S	I	I	I	S	I	S	S
Al ³⁺	I	S	S	S	I	D	I	S	-	S	-

Key: S = Soluble in water I = insoluble in water (less than 1g/100g H₂O)
 s = slightly soluble in water d = decompose in water

PERIODICTABLE

Periodic Table of the Elements

Periodic Table of the Elements																18 VIII 8A																													
1 IA 1A		2 IIA 2A												13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 He Helium 4.003																										
1 H Hydrogen 1.008	3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180																											
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948											19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798										
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.906	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.6	53 I Iodine 126.905	54 Xe Xenon 131.29											55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226	89-103 Actinide Series	104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 266	107 Bh Bohrium 264	108 Hs Hassium 277	109 Mt Meitnerium 268	110 Ds Darmstadtium 271	111 Rg Roentgenium 272	112 Cn Copernicium 285	113 Nh Nihonium 284	114 Fl Flerovium 289	115 Mc Moscovium 288	116 Lv Livermorium 293	117 Ts Tennessine 294	118 Og Oganesson 294																												
																		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967													
																		89 Ac Actinium 227	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.083	99 Es Einsteinium 252.083	100 Fm Fermium 257.103	101 Md Mendelevium 258.103	102 No Nobelium 259.103	103 Lr Lawrencium 262.103													
																		Alkali Metal	Alkali Earth	Transition Metal	Basic Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal	Transition Metal											